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EFFECT OF VOLATILITY AND OXYGENATES ON DRIVEABILITY AT INTERMEDIATE AMBIENT TEMPERATURES

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EFFECT OF VOLATILITY AND OXYGENATES ON DRIVEABILITY AT INTERMEDIATE AMBIENT TEMPERATURES

(CRC Project No. CM-118-89)

Prepared by the

CRC Volatility Group

MARCH 1992

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

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I. INTRODUCTION

Recent regulations reduce summertime fuel front-end volatility by limiting fuel Reid vapor pressure (RVP) to values considerably less than past commercial practices. There has been some concern that such reduced-RVP fuels may lead to degraded driveability, especially in areas with long distribution lead times and low tank turnover rates. In those areas, significant volumes of these fuels may be sold in cool spring weather in order to ensure that the RVP regulations are met at the start of the summer control period.

The 1989 CRC driveability program investigated the independent effects of front-end volatility and mid-range volatility on cold-start and warmup driveability of late model vehicles at intermediate ambient temperatures. Front-end volatility was measured by RVP, and mid-range volatility was measured by the temperature at which 50 percent of the fuel is evaporated (T_{50}). Volatility ranges investigated were those that may be required of future summertime fuels. Classical volatility levels were included for comparison. The study included both hydrocarbon and gasoline-oxygenate blends. The program was conducted in Yakima, Washington, from October 9 through November 18, 1989. Test temperatures were 30°F to 56°F.

Members of the Data Analysis Panel and participants in the test program are shown in Appendices A and B, respectively. Appendix C outlines the proposed program as approved by the CRC Volatility Group, and Appendix D details the fuel/vehicle assignments for each test day. Key findings of the test program, issued in June 1990, are attached to this report as Appendix E.

II. SUMMARY AND CONCLUSIONS

Analysis of the data provided the following conclusions:

- Carbureted and TBI vehicles performed at a similar driveability level and responded to fuel type and volatility in a similar manner.

- PFI vehicles exhibited substantially better driveability than carbureted or TBI vehicles in all cases.

- PFI vehicles showed little or no response to changes in front-end volatility (RVP or T_{10}), but showed some degradation in driveability at high T_{50} levels.

- Carbureted and TBI vehicles responded to both front-end and mid-range (T_{50}) volatility; however, a 40°F change in T_{50} always had more effect on driveability than a 4.5 psi change in RVP.

- Driveability cannot be expressed as a simple linear function of the independently controlled volatility factors across the complete data set. At high volatility levels (high RVP and low T_{50}), there is less response to fuel changes than at low volatility levels.

- RVP-controlled splash blends containing 15 volume percent MTBE generally provided the best driveability, followed by hydrocarbon fuels and then corresponding blends containing 10 volume percent ethanol; however, these rankings varied somewhat among volatility levels.

- Using the volatility scale developed with these data, the 15 volume percent MTBE fuels and the hydrocarbon fuels overall exhibited similar performance at the same volatility levels, while the 10 volume percent ethanol fuels exhibited degraded performance; although at the lower volatilities used in this program, the differences among the three fuel types were small.

III. TEST VEHICLES

The test fleet is shown in Table 1. Of the twenty-four 1988 and 1989 model-year rental vehicles tested, twenty were passenger cars, and four were light trucks. Fuel-delivery system was balanced among port-fuel-injected (PFI), throttle-body-injected (TBI), and carbureted; there were eight of each. Twenty vehicles had automatic transmissions, and four had manuals. The PFI vehicles were designated as numbers 1 - 8, the TBI as numbers 9 - 16, and the carbureted as numbers 17 - 24. The three additional cars shown at the bottom of Table 1, numbers 25 - 27, were included in order to develop rater correction factors, if necessary.

Each vehicle was prepared for testing by installing fuel tank drains, fuel tank drain hoses, fuel tank thermocouples, manifold vacuum taps, and vacuum lines. No additional mechanical work was performed on the vehicles unless it was necessary for the continuance of the test program. Consequently, all of the vehicles were tested in an "as-received" condition. At the completion of the program, all test equipment was removed from the vehicles.

IV. TEST FUELS

The fuel matrix was designed to allow independent evaluation of front-end volatility, mid-range volatility, and oxygenate effects on cold-start and warmup driveability. To achieve this, three fuels sets were required: one set with fuels containing only hydrocarbons, one set with fuels containing ethanol, and one set with fuels containing MTBE.

Independent evaluation of front-end and mid-range volatility requires a 2 x 2 square of fuels. A midpoint fuel was added to allow evaluation of nonlinearity. Thus, each fuel set contained five fuels for a total of fifteen test fuels.

It should be noted that the test fuels form three parallel squares with centerpoints. The relationship between squares is splash-blending with RVP compensation. It should also be kept in mind that within each square, independent evaluation of RVP and T_{50} effects is possible.

The specification of front-end volatility for all fuels was set using RVP. The high volatility level was set at 11.5 psi, the low level at 7 psi, and the midpoint level at 9 psi. Mid-range volatility was specified using T_{50} (the temperature at which 50 percent of the fuel has evaporated, as defined by ASTM D 86). Because the fuels were splash-blended, however, the T_{50} levels vary between fuel sets. All fuels were required to have a minimum (R+M)/2 octane rating of 88. Aromatics were limited to 40 percent and Benzene was limited to 3 percent. Antioxidants and corrosion inhibitors were required in all fuels. Table 2 contains the final volatility properties for all fifteen fuels.

The test fuels were blended from five base stocks described in Table 3. Each base stock was the starting point for one fuel in each fuel set; thus, the base stocks also form a 2 x 2 square with a centerpoint. The target specifications for the base stocks were: 10.5 psi RVP and 120°F T_{10} for high front-end volatility, 5.5 psi RVP and 148°F T_{10} for low front-end volatility, 200°F T_{50} for high mid-range volatility, and 245°F T_{50} for low mid-range volatility. The centerpoint fuel had a target RVP of 8 psi, T_{10} of 133°F, and T_{50} of 225°F. T_{90}, a measure of tail-end volatility, was held constant at 340°F.

The hydrocarbon test fuels were prepared by pressurizing the base stocks with butane to meet the test fuel RVP specifications. The ethanol test fuels were prepared by adding ethanol to the base stock and pressurizing with butane in order to meet the RVP specification for the test fuel and yield a final ethanol content of 10 percent by volume.

The MTBE test fuels were produced by adding MTBE to the base stocks and pressurizing with butane to achieve the RVP specification and yield a fuel containing 15 percent MTBE by volume. This test fuel blending strategy is illustrated in Figure 1.

Once blended, samples of both the base stocks and the test fuels were analyzed by the fuel supplier and individual participating laboratories. There was a total of six laboratories submitting analyses of the test fuels; two of those six plus an additional lab analyzed the base stocks. Individual laboratory fuel properties are summarized in Appendix F. Due to problems in shipping, improper values were obtained for Fuel 5 in four of the six analyses; however, two laboratories received unaltered Fuel 5. Thus, the data displayed in Table 2 are the averages of the values obtained at the six laboratories, except for Fuel 5. Fuel 5 values in Table 2 are the averages of the two laboratories which received unaltered fuel, corrected for the offset between the two labs and all six labs. This offset was determined individually for each volatility parameter by comparing the average value for the six labs to the average value for the two labs for each fuel except Fuel 5. For each parameter, the average of these offsets (for fourteen fuels) was applied to Fuel 5 to place it on the same basis as the other fourteen fuels.

Finally, all the data points were checked to see if statistically they were outliers. Only one outlier was found which was an RVP value for Fuel 6, and that value was dropped.

V. TEST FACILITIES

The program was conducted at the Renegade Raceway drag strip in Yakima, Washington. The drag strip is a level, paved 3900-foot-by-65-foot asphalt track with a staging area for parking test vehicles. A schematic of the test site and driving cycle is shown in Figure 2. Additional facilities included electrical power, restroom, fuel storage area, equipment storage building, and access to local roads with low traffic density. The track is at an altitude of 990 feet.

An electical fuel pump was used to drain the vehicle fuel tanks. A manifold allowed simultaneous draining of three vehicles.

VI. TEST CONDITIONS

The target test temperatures for the program were 30°F - 50°F. Over 99 percent of the tests were conducted within a temperature range of 30°F - 56°F. The maximum test temperature of the remaining tests was 60°F. Mean test run temperatures are shown in Table 4 by fuel system and fuel type. Testing was scheduled to begin at dawn each day. Temperatures at the track in the early morning hours were very stable. On most days, the temperature rise in the 2.5 hours required for testing, starting at dawn, was only about 5°F. There was only one day on which the temperature at dawn was less than 30°F. Testing was delayed on that day until ambient temperatures reached 30°F. On several test days, testing was begun at 50°F - 55°F ambient temperatures. Of 810 test runs, only 15 percent (118) were made at temperatures above 50°F.

Testing was cancelled one day because of rain and one day because of high ambient temperatures (60°F at dawn). On several other days, there was a trace of rain that either stopped or did not interfere with testing.

VII. TEST DESIGN

The test program was conducted in two three-week phases. For each phase, the test fleet was divided into three groups of eight vehicles each: Red, Blue, and Yellow Groups. Each vehicle group included a mixture of the three fuel delivery systems - PFI, TBI, and carbureted. In Phase I, conducted from October 9-31, 1989, each of three driver-raters was assigned a vehicle group to evaluate on all fifteen test fuels. During Phase II, conducted from October 31 to November 18, 1989, the same three vehicle groups were evaluated by three different driver-raters. In this manner, each fuel was tested in duplicate in each vehicle.

Fueling schedules for the two phases are presented in Appendix D. These schedules were not random. Three fuels, one of each composition (hydrocarbon, ethanol, MTBE), were tested each day in order to minimize the impact on individual fuels supplies if it became necessary to abort a test day. This did not occur in the program.

For each driver-rater, test fuel composition was changed on a daily basis (e.g., MTBE fuels were not evaluated on consecutive days). These fuel composition changes for individual raters were random.

Three additional vehicles were also evaluated each day, one per rater, using Fuel 4. These results were collected in case rater severity corrections became necessary to adequately analyze the fleet driveability data.

VIII. TEST PROCEDURE

The test procedure was a modified version of the CRC Cold-Start and Warmup Driveability Procedure. The driving procedure was preceded by draining the test vehicle's fuel tank, adding the prescribed amount of test fuel, and disconnecting the battery power to the electronic control module for a minimum of one minute to clear the adaptive memory. The adaptive memory was reprogrammed to the new fuel using the following driving procedure. All vehicles were "warmed-up" by driving fifteen miles using a schedule that included steady states of 5, 15, 25, 35, 45, and 55 miles per hour each for a quarter-mile, and a full stop with a moderate acceleration up to 55 miles per hour. The vehicles were then driven the last cycle of the Cold-Start and Warmup Driveability Procedure. The vehicles were then parked and allowed to soak overnight at ambient temperatures. All vehicles were started the next day and driven the first four cycles of the Cold-Start and Warmup Driveability Procedure. Driveability malfunctions were recorded for the series of engine idles, accelerations and decelerations, and constant speed cruises; these malfunctions appear as demerits in Appendix G. All analysis is based on the demerits for these four cycles. A detailed description of the test procedure and rating system is given in Appendix C.

The driving technique for manual transmission vehicles was modified to minimize demerits associated with clutch operation and gear changes. Shift speeds, gear selection, and throttle were selected to give smooth warmed-up operation while meeting test requirements for acceleration and speed. Gear selections were as follows:

Maneuver	Gear
0-25 Light Throttle	1 & 2
25 mph Cruise	3
25-35 Detent	2
0-35 Wide-Open-Throttle	1 & 2
10-25 Light Throttle	2
0-45 Crowd	1, 2 & 3
Idle	1

IX. DISCUSSION OF RESULTS

IX. A. Total Weighted Demerits (TWD)

1. Analysis

All malfunctions observed were weighted and totaled for each run following the demerit schedule and weighting procedures shown in Appendix C.

Analysis of variance (ANOVA) was used to determine the significance of the independent variables. Fuel type (HC, EtOH, MTBE), fuels within fuel type (volatility level as characterized by RVP and T_{50} or T_{10} and T_{50}), vehicle fuel system (carbureted, TBI, PFI), vehicles within the fuel system, transmission type, and run temperature were significant cold-start and warmup variables. These variables were, therefore, included when developing the performance models.

2. Performance Models

Regressions were made on the basis of TWD, square root of TWD, and ln TWD (ln TWD was not found to add any additional information and is not presented). Fuel volatility variables were RVP and T_{50} or T_{10} and T_{50}. Since T_{10} and RVP are intercorrelated, results are largely the same. Figure 3 shows the relationship between T_{10} and RVP. Both are presented because legislation and restrictions on fuel volatility are based on RVP, but past CRC driveability program results have used T_{10} to characterize front-end fuel volatility

Table 5 presents the regression coefficients for models using TWD and square root of TWD with RVP and T_{50} fuel characterization parameters. There are fifteen equations shown for each model (five transmission-fuel system combinations for each of three fuel types). It should be pointed out that in the case of manual transmission vehicles, the equations are based on only two vehicles. For automatic transmission vehicles, the data represent six or eight vehicles. A comparison of the upper portion of Table 5 (TWD regressions) to the lower portion of the table (square root of TWD regressions) indicates that the same terms can be termed statistically significant using either model. In general, the R^2 value is slightly higher using the square root of TWD, but the differences are not appreciable.

Discussion will, therefore, be limited to the TWD models, because understanding TWD effects and the magnitude of coefficients is much easier. Since the square root of TWD analysis does not add much in identification of significant effects or improvement in fit, the complications and/or loss of easy understanding does not appear justified.

In the case of the MTBE fuels, the RVP x T_{50} interaction term was highly significant for both the carbureted and TBI automatic transmission vehicles. Generally, coefficients for carbureted and TBI automatic transmission vehicles were similar, indicating a general similarity in response to fuel volatility changes. Fuel volatility term coefficients for these vehicles were appreciably larger than those for PFI automatic transmission vehicles, indicating the generally smaller response of PFI vehicles to changes in fuel volatility.

Also shown are the coefficients for the run temperature for each regression category (for run temperatures expressed in degrees Fahrenheit). The temperature coefficients are larger for manual transmission vehicles than for automatics, and larger for the EtOH fuels than for the HC or MTBE fuels.

Table 6 presents the same equations as Table 5, except that T_{10} is used to characterize the front-end fuel volatility instead of RVP. By comparing the T_{50} and temperature coefficients and R^2 values between Tables 5 and 6, it can be observed that use of either T_{10} or RVP yields the same results.

The temperature coefficients shown in these tables were used to generate "corrected" or normalized TWD values to 40°F. These normalized TWD values, as well as the raw TWD values for each run, are shown in Appendix G.

Appendix G also shows average temperature-corrected TWD for different vehicle groupings on each fuel type for each of the four regression models.

3. Displays of RVP and T_{50} Effects

There are many ways the various vehicles in the program can be grouped to display the response of driveability (corrected TWD) to fuel volatility; thirty-three such plots were prepared. Nine of the plots will be discussed here encompassing each of the three fuel types in each of the three vehicle fuel delivery systems. The remaining plots may be found in Appendix H.

Figures 4 through 6 display the corrected TWD values for carbureted vehicles versus RVP for HC, MTBE, and EtOH fuels, respectively. Shown on each plot is a line for the high T_{50} fuels (and the nominal T_{50} value) and the lower T_{50} fuels. Figure 4 shows that in carbureted vehicles using HC fuels, increasing RVP by 4.5 psi decreases demerits by 12 - 13 TWD. It also shows that increasing T_{50} by about 40°F from 200°F to 240°F increases demerits by about 40 TWD. Figure 5 shows the change in demerits using MTBE fuels. The differences shown due to increasing T_{50} or increasing RVP are smaller than the differences shown in the previous figure for HC fuels. Figure 6 shows the relationship of the EtOH fuel results in carbureted vehicles. The general response appears similar to the HC response curves, except that at low T_{50}, there was no improvement in driveability noted with the increase in RVP from 6.5 to 11 psi.

Figures 7 through 9 show the effects of fuel volatility in the TBI vehicles. The initial observation is that all TWD values of the TBI vehicles are lower than the carbureted vehicles in the preceding figures. This is primarily due to the fact that all eight vehicles in the TBI category are automatic transmission vehicles. In general, the manual transmission vehicles had higher demerits than the automatic transmission vehicles. Actual carbureted automatic transmission vehicle demerit levels were similar to the TBI vehicle demerit level. The response to fuel volatility for HC fuels in the TBI vehicles was very similar to that shown for carbureted vehicles; a large increase in TWD associated with a 40°F increase in T_{50}, and a much smaller decrease in TWD associated with a 4.5 psi increase in RVP. Figure 8, which displays the MTBE results, shows the significant RVP x T_{50} interaction noted in Table 5. Increasing RVP at low T_{50} values resulted in increased TWD. At the higher T_{50} values, the response to RVP is very similar to that for HC fuels. Figure 9 shows the responses for EtOH fuels in these vehicles. Relative response is about the same as shown for HC fuels; i.e., a much larger change in TWD due to T_{50} changes than for a 4.5 psi change in RVP.

Figures 10 through 12 show the data for PFI vehicles. For HC fuels shown in Figure 10, the demerits are much lower than the previous fuel delivery system classifications, even though there are two manual transmission vehicles in this classification. The plot indicates no benefit associated with higher RVP fuels, but an appreciable change in TWD with changes in T_{50}. For the MTBE fuels in Figure 11, there appears to be little if any effect of fuel volatility on driveability. Figure 12 shows the EtOH fuel performance which appears similar in responses to the plots shown previously for TBI and carbureted vehicles: a large effect of T_{50} and a much smaller effect of RVP on driveability.

Other displays for manual transmissions, automatic transmissions, all vehicles, etc. are located in Appendix H.

4. Oxygenate Effects

The analyses presented thus far have shown the major effects of RVP and T_{50} and the three fuel types on driveability. There is, of course, interest in the relative performance of the individual test fuels and responses to presence and type of oxygenate for RVP-adjusted splash blends. Figure 13 shows the least square means (LSM) driveability demerits. The effects of all significant variables are discussed in terms of the LSM for each factor level. LSM are a method of averaging, performed by the General Linear Model (GLM) procedure, which averages the effect over all the other test variables in the model. This figure compares the driveability demerits for EtOH, hydrocarbon, and MTBE fuels for each volatility level studied. For LH (low RVP, high T_{50}), LL (low RVP, low T_{50}) and HH (high RVP, high T_{50}), there is a great distinction between hydrocarbon fuels and oxygenate-containing fuels. In these three cases, EtOH increased driveability demerits, while MTBE reduced demerits. For the more volatile fuels, oxygen presence had less impact on driveability performance. In the case of the fuels having high RVP and low T_{50} (HL), the EtOH- and MTBE-containing blends were about equal, with the hydrocarbon

fuel being directionally better. For the centerpoint fuels (MN), the EtOH and MTBE blends also gave similar performance, with the hydrocarbon fuel being somewhat poorer. This further illustrates that simplistic straight-line relationships between driveability performance and volatility are inadequate.

Data in Figure 13 are grouped according to the fuel blending strategy described in Figure 1. This means that, at any given volatility level, RVP values are equal, but T_{50} values vary due to the blending characteristics of MTBE and ethanol.

5. Expressions Relating Total Weighted Demerits to Fuel Volatility

Separate expressions relating TWD to fuel volatility were made for each combination of fuel delivery system, transmission type, and fuel composition (Tables 5 and 6). Such expressions are not very useful for comparing different fuel compositions on a common volatility scale. Such comparisons could be and have been made by plotting results as a function of the ASTM Driveability Index (DI = 1.5 T_{10} + 3 T_{50} + T_{90}); however, DI is not the best, and is possibly not an unbiased predictor for the average vehicle on the average fuels used in this program, since it was not internally generated from these data. DI's were developed for hydrocarbon fuels, and this data base contains oxygenated fuels as well as hydrocarbon fuels. Therefore, a common expression was generated for all fuels and vehicles for this program to facilitate comparisons between fuels and vehicle types on a common scale which best represents the average performance of the fuels in this program. The data representing this expression are given in Table 7. The following expression relates the "Yakima Volatility Factor 1," YVF 1, to RVP and T_{50}:

$$YVF\ 1 = -2.0\ RVP + 0.54\ T_{50}$$

The YVF 1 is not the "best" model for any individual fuel set, but it gives the best fit for the entire data set, and is unbiased for a comparison of fuels.

It should be noted that YVF 1 is a composite regression fit for the entire fleet of twenty-four vehicles. Other equations based upon subsets of the fleet, such as PFI or PFI automatic transmission vehicles, show a different balance of volatility terms in regression equations than YVF 1.

The general concept of a two-segment line or nonlinear fit to driveability data should be expected; that is, as volatility of the fuel is increased, TWD's will decrease. Since not all driveability problems are volatility-related, however, a point will be reached at which further increases in volatility will not produce an incremental decrease in TWD's.

Figure 14 shows the average corrected TWD values for the fleet of twenty-four vehicles for each fuel composition as a function of YVF 1. Because of the presence of a significant interaction term effect (RVP x T_{50}), particularly in the MTBE fuels, the fit of the nonlinear data to the simple two-term expression is inadequate. To demonstrate this, two straight line segments have been fitted to each of three curves. This is the same effect seen in Figure 8.

The fit of the HC data is excellent and indicates the general increase in TWD with decreasing volatility (increasing YVF 1). The minor break in the curve as shown is not necessary; a single straight line would fit just as well. The two-segment line is only shown to treat all fuel compositions in the same manner. It is possible that the reason a straight line fits the hydrocarbon fuels so well is that the YVF 1 of the hydrocarbon fuels does not range low enough to show a reaction similar to the oxygenate-containing fuels. Caution should, therefore, be exercised not to extrapolate beyond what the data actually show.

The MTBE two-line fit is excellent, and is necessary. The slight increase in TWD with increasing volatility (decreasing YVF 1) at the left side of the figure is probably not important. At higher levels of YVF 1, the MTBE curve is very similar to the HC curve.

The interpretation of the HC and MTBE curves is that at equal volatility levels as expressed by YVF 1, the performance of MTBE and HC fuels is very similar. For convenience, the location of four select RVP-T_{50} combinations which generally encompass the range of volatility investigated are shown on the YVF 1 axis.

The EtOH fuel curve is displaced from both the MTBE and HC curves and demonstrates higher TWD at all volatility levels. There is a good deal of uncertainty in the EtOH curve at the lower values of YVF 1 (less than about 100) where average warming-up performance is relatively good as indicated by lower TWD values. At the higher levels of TWD and YVF 1, however, the fit is good and demonstrates an increase of approximately 10-15 demerits at the same volatility levels as HC or MTBE fuels.

Since volatility expressions that use only distillation points in the regression equations are generally more familiar, YVF 2, which is based upon T_{10} and T_{50}, was developed for the fleet of twenty-four vehicles:

$$YVF\ 2 = 0.40\ T_{10} + 0.52\ T_{50}$$

The TWD data for all three fuel types are shown in Figure 14. Since T_{10} and RVP are both measures of front-end volatility and are thus highly correlated, the curves for YVF 2 appear the same as those for YVF 1 and the same comments apply.

XI. B. FUEL TANK TEMPERATURES

Thermocouples were installed in the fuel drain line fitting elbows of all twenty-four test vehicles. Fuel tank temperatures were monitored during the warmup cycle after refueling. As described in Section VIII, the warmup cycle was fifteen miles long and consisted of a series of low-speed steady-state conditions, light accelerations, a hot restart, a 55-mph cruise on local roads, and the fourth cycle of the cold-start and warmup driveability procedure upon returning to the test track and parking for the next day's test work. The warmup took about thirty minutes to complete. There were six temperature readout devices available to monitor temperatures during warmup. In general, there were eight or nine personnel available to perform the required warmup runs; therefore, it was not possible to obtain fuel tank temperature rise data on all vehicles each day. In the fifteen-day test period of Phase I, temperatures were recorded in each vehicle at least nine times.

Neither fuel tank temperature nor starting ambient temperature at the beginning of the warmup cycle was controlled. At times, fuel tank temperature at the beginning of the warmup cycle was above ambient, and at times the temperature was below ambient. Data recorded on two days were discarded because of rain and/or wet roads which appeared to have reduced fuel tank temperature rises.

Table 8 shows the average fuel tank temperature increases for each of the twenty-four vehicles during Phase I. Data are presented as both the final tank temperature minus the initial fuel tank temperature, and as the final tank temperature minus ambient temperature. The table indicates a large range of tank temperature increases from vehicle to vehicle, from 9°F to 24°F for the fifteen-mile warmup cycle.

Table 9 summarizes the data by fuel delivery system type and by fuel tank composition. The table indicates that fuel tank temperature increases in fifteen miles of driving are 4°F to 6°F higher with fuel injection vehicles than with carbureted vehicles. The data also indicate that plastic fuel tank temperature rises average about 3°F less than metal tanks.

During Phase II, it was decided to use available manpower to run extended warmup cycles on six vehicles to determine if fuel tank temperature had reached equilibrium in the 30-minute warmup cycle. Two complete warmup cycles were run on these six vehicles for a total of thirty miles and about one hour. The six vehicles selected were a high-temperature-rise vehicle and a low-temperature-rise vehicle from each of the three fuel delivery system types. Table 10 summarizes these data. Shown in addition to the two temperature rise computation methods are the data after fifteen miles and thirty miles during the same runs. Data are the average of nine to eleven runs in each vehicle. The data indicate that the additional fifteen-mile cycle contributed only 2°F to 3°F to the temperature rise compared with the 10°F to 23°F observed in the first fifteen miles.

IX. C. RATER CORRECTION FACTORS

Previous CRC driveability programs have used rater correction factors to normalize data (TWD) to an "average" driver result. Since it is not possible to have all drivers rate all fuels in all vehicles, this is usually required to permit comparisons of individual vehicles and individual fuels on a common basis. Some programs have used a separate fleet of vehicles to generate rater comparison data, and other programs have attempted to generate such data from within the data set.

The fuel/vehicle/rater schedule used in this program did not require the development of rater correction factors. The main objective of the program was to maximize the reliability of observed fuel-to-fuel effects on performance at the expense of comparing individual vehicle performance levels. In each phase of the program, therefore, one driver rated the performance of all fifteen fuels in any one vehicle. Vehicle/rater assignments were made to balance the major vehicle groupings so that each rater contributed about equally to each expected vehicle grouping of data such as carbureted, TBI, and PFI fuel delivery systems. The second phase of the program was a complete replicate of the first phase with three replacement drivers.

The anticipation that driver corrections would not be required was based on the assumption that the predetermined fuel/vehicle/rater assignment schedule could be conducted without major revisions which might be caused by weather, illness, or unforeseen personnel changes. It was, therefore, decided to run a three-vehicle rater comparison fleet as a backup to the data for use in data analysis if required. Fortunately, the program proceeded as scheduled and it was not necessary to use the "correction factor" data.

Three vehicles (one each carbureted, TBI, and PFI) were rated each day by one of the raters. The same fuel, Fuel 4, was used each day. Fuel 4 was the lowest volatility HC fuel. The three vehicles were treated the same as the other test vehicles (warmup, etc.) except that there was no need to drain the fuel tank each day. These vehicles did not have fuel drain lines.

There were five TWD ratings by each of the six drivers in each of the three vehicles. Data are shown in Table 11. Data have been averaged for each driver in each vehicle and a relative severity computed for each rater/vehicle combination. Also shown at the bottom of the table is the three-vehicle average severity for each driver.

The average severity ranges from 0.73 to 1.28. Although this may appear to be a large range, it is not unexpected. Rater 3 would appear to be the least critical and Rater 4 or 5 the most critical. Raters 1 and 6 would appear to be "average"; however, in individual vehicles, the comparisons are sometimes very different. In Vehicle 25, Rater 1 was the least severe, only generating 54 percent of the average demerit levels, and Rater 6 was the least severe in Vehicle 26. On the other hand, Raters 2 and 3 maintained a relatively stable severity rating relative to the group of six raters across the three vehicles.

It is apparent that in some cases drivers may respond to a change in vehicle (or presumably a change in fuel) in similar fashion or very differently. For example, if Rater 1 had been unable to complete his driving assignment on one or more vehicles, and Rater 6 were assigned the makeup run in his absence, one would assume no rater adjustment would be necessary (0.97 versus 0.94 severity factors). If the vehicle performed as Vehicle 25, however, a 50 percent reduction in Rater 6's ratings might have been proper. If the unknown vehicle had performance similar to Vehicle 26, a 50 percent increase in Rater 6's ratings would have been more proper to substitute into the data set.

Fortunately, there was no need to substitute any rater assignments and these correction factors were not used.

IX. D. Analysis of Cold Cycle, Idle, and Last Cycle Demerits

Historically, the cold-start and warmup test cycle has been longer than the test cycle used in this program. This gradual truncation of the test cycle is justified by improvements in vehicles over the last twenty years; however, contribution by the last cycle in this current test to the total demerits for the fleet should be analyzed.

The data have been divided into cold, warm, and stationary demerits. Cold demerits are those recorded during the first three cycles, but not during start-up. Warm demerits are those recorded during the fourth (final) cycle. Idle demerits are those recorded at all idles, and include start-up; idle demerits thus overlap with the previous two categories.

Analysis of each of these demerit categories was performed with temperature correction and rater correction for each fuel type. The T_{10} and T_{50} dependence of the cold demerits is quite comparable to the dependence of total demerits on these parameters, as shown in Table 12. This is not surprising, as the majority of demerits occur during the first three cycles.

By contrast, the T_{10} and T_{50} coefficients for the warm demerits are an order of magnitude smaller than the coefficients for total demerits. This is true for all fuel types. Furthermore, many of these coefficients are not statistically different from zero. Thus, the last cycle shows an extremely weak volatility dependence, as well as a low absolute number of demerits. It has little influence on the trends observed as a function of volatility.

The idle demerits are similar in nature to the fourth cycle demerits. Again, the absolute level is low, and the coefficients of the volatility parameters are nearly an order of magnitude smaller than those for total demerits. Idle demerits, therefore, also have little influence on the trends observed as a function of volatility, regardless of fuel type.

In general, the volatility dependence of total weighted demerits occurs in the first three cycles. The idle demerits and final cycle demerits contribute only to the absolute level.

TABLES AND FIGURES

TABLE 1

TEST VEHICLES

Model Year	Make/Model	Displacement liters	Fuel System
Test Vehicles			
1988	Ford Mustang	5.0	Port-Fuel-Injected
1988	*Ford F-150 Pickup	4.9	Port-Fuel-Injected
1988	Oldsmobile 98	3.8	Port-Fuel-Injected
1989	Chrysler New Yorker	3.0	Port-Fuel-Injected
1989	Ford Aerostar	3.0	Port-Fuel-Injected
1989	Chevrolet Celebrity	2.8	Port-Fuel-Injected
1989	Oldsmobile Cutlass Calais	2.3	Port-Fuel-Injected
1988	*Nissan 200SX	2.0	Port-Fuel-Injected
1988	Dodge Ram LE350 Van	5.2	Throttle-Body-Injected
1989	Buick Century	2.5	Throttle-Body-Injected
1988	Ford Taurus	2.5	Throttle-Body-Injected
1989	Plymouth Acclaim	2.5	Throttle-Body-Injected
1989	Plymouth Sundance	2.5	Throttle-Body-Injected
1989	Chevrolet Cavalier	2.0	Throttle-Body-Injected
1989	Ford Escort	1.9	Throttle-Body-Injected
1989	Honda Civic	1.5	Throttle-Body-Injected
1989	Chrysler Fifth Avenue	5.2	Carbureted
1989	Chevrolet Caprice Station Wagon	5.0	Carbureted
1989	Jeep Wrangler	4.2	Carbureted
1989	Honda Prelude	2.0	Carbureted
1988	*Dodge Ram 50 Pickup	2.0	Carbureted
1988	Chevrolet Spectrum	1.5	Carbureted
1988	*Ford Festiva	1.3	Carbureted
1988	Chevrolet Sprint	1.0	Carbureted
Rater Comparison Vehicles			
1989	Oldsmobile Cutlass Ciera	3.3	Port-Fuel-Injected
1989	Chevrolet Spectrum	1.5	Carbureted
1989	Honda Civic	1.5	Throttle-Body-Injected

* Indicates vehicle had manual transmission.

Note: Rater compaison vehicles were tested only on Fuel 4 throughout the program to assist in developing rater correction factors, if necessary.

TABLE 2

TEST FUEL PROPERTIES

	Hydrocarbon Fuels					15 vol. % MTBE Blends					10 vol. % Ethanol Blends				
Fuel	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RVP, psi	11.1	6.5	11.1	6.7	9.0	10.9	6.8	11.0	6.7	8.6	11.3	6.8	11.3	6.9	8.8
Distillation, % Evap., °F															
IBP	81	101	84	95	85	82	102	84	94	91	8	109	89	106	95
T_5	101	133	104	129	102	105	130	99	128	115	105	129	106	132	118
T_{10}	114	145	119	147	122	115	139	113	142	127	116	134	120	140	126
T_{20}	134	159	152	175	144	131	149	137	160	142	128	139	139	150	137
T_{30}	157	172	192	201	170	146	158	163	176	158	140	145	154	159	147
T_{40}	181	185	225	222	197	162	168	189	195	176	149	152	177	199	159
T_{50}	204	199	246	241	222	181	181	217	220	199	170	185	234	234	208
T_{60}	224	214	265	260	238	204	198	247	246	224	215	207	257	254	233
T_{70}	246	237	284	279	259	231	221	272	270	248	239	227	279	275	253
T_{80}	279	283	304	301	290	266	263	296	294	278	274	269	300	298	283
T_{90}	335	336	333	343	337	326	328	324	330	328	332	331	328	336	332
T_{95}	368	360	372	386	365	362	352	353	376	365	364	355	359	381	366
EP	420	410	420	433	429	412	405	414	425	417	416	408	415	426	409

TABLE 3

BASE FUEL PROPERTIES

Fuel	A	B	C	D	E
RVP, psi	10.2	5.4	10.1	5.6	7.6
Distillation, % Evap., °F					
IBP	91	99	90	102	83
T_5	112	142	108	130	116
T_{10}	118	151	124	152	132
T_{20}	136	163	158	178	153
T_{30}	158	175	198	202	176
T_{40}	182	188	228	224	200
T_{50}	203	201	248	243	222
T_{60}	226	218	267	260	238
T_{70}	248	242	286	280	258
T_{80}	284	292	305	300	288
T_{90}	338	338	332	340	335
T_{95}	368	360	364	382	363
EP	419	417	424	436	423

TABLE 4

MEAN RUN TEMPERATURES FOR 1989 CRC DRIVEABILITY PROGRAM

Fuel Type	Fuel No.	PFI Cars Auto (6)	PFI Cars Manual (2)	PFI Cars Total (8)	Carbureted Cars Auto (6)	Carbureted Cars Manual (2)	Carbureted Cars Total (8)	TBI Cars Auto (8)	Fleet Auto (20)	Fleet Manual (4)	Fleet Total (24)
HC	1	43.8	42.8	43.6	44.3	36.8	42.4	42.7	43.5	39.8	42.9
HC	2	46.0	41.3	44.8	47.3	36.5	44.6	44.2	45.6	38.9	44.5
HC	3	42.9	41.5	42.6	42.5	36.8	41.1	41.0	42.0	39.1	41.5
HC	4	42.2	45.0	42.9	44.4	51.0	46.1	45.1	44.0	48.0	44.7
HC	5	39.3	46.0	41.0	40.4	45.8	41.8	42.6	40.9	45.9	41.8
MTBE	6	42.2	43.8	42.6	41.8	47.0	43.1	42.1	42.0	45.4	42.6
MTBE	7	44.3	40.5	43.3	46.1	36.0	43.6	45.2	45.2	38.3	44.0
MTBE	8	39.6	44.5	40.8	39.3	42.0	39.9	39.8	39.5	43.3	40.2
MTBE	9	46.4	44.5	45.9	47.8	45.3	47.1	47.1	47.1	44.9	46.7
MTBE	10	41.8	44.3	42.4	39.8	42.5	40.5	40.4	40.7	43.4	41.1
EtOH	11	42.0	44.0	42.5	44.1	50.5	45.7	45.4	44.0	47.3	44.5
EtOH	12	45.0	41.3	44.1	45.4	39.5	43.9	44.4	44.9	40.4	44.1
EtOH	13	37.8	38.3	37.9	40.4	38.5	39.9	40.1	39.5	38.4	39.3
EtOH	14	42.3	41.5	42.1	40.8	43.5	41.4	43.4	42.3	42.5	42.3
EtOH	15	44.8	48.0	45.6	42.7	48.8	44.2	45.2	44.3	48.4	45.0

TABLE 5

Regression Coefficients Using RVP

Variable	Fuel Type	Fuel System	Trans-mission	Average Intercept	RVP	T50	Temp	RVPxT50	Root MSE	R-Sq
TWD	HC	PFI	Auto	-60.867	-0.3005	0.3898**	-0.06412	------	12.45	47.4
		PFI	Manual	5.9966	1.5739	0.5049	-1.8830	------	30.59	86.7
		Carb	Auto	-73.830	-3.6135**	0.8252**	-0.4176	------	22.18	60.4
		Carb	Manual	26.969	-6.1633	0.9310*	-1.3505	------	32.89	51.2
		TBI	Auto	-34.354	-4.7485**	0.8019**	-1.2200**	------	22.11	55.4
	MtBE	PFI	Auto	-22.214	0.3376	0.1552*	0.1205	------	10.25	34.7
		PFI	Manual	66.820	-2.0371	0.08620	-0.4879	------	28.48	84.9
		Carb	Auto	-316.81	28.542**	1.7608**	0.4426	-0.1464**	16.82	67.0
		Carb	Manual	310.17	-33.624	-0.5462	-1.4775	0.1475	27.50	60.3
		TBI	Auto	-237.12	26.010**	1.5600**	-0.5795	-0.1338**	17.95	45.8
	EtOH	PFI	Auto	-9.1625	-1.0020	0.3685**	-0.8161**	------	19.65	48.3
		PFI	Manual	41.106	-6.2819	0.7881**	-2.1665*	------	32.79	88.9
		Carb	Auto	52.054	-2.1180	0.4240**	-1.1606**	------	20.23	65.6
		Carb	Manual	20.082	4.9543	0.8594**	-2.5049	------	38.08	60.2
		TBI	Auto	24.048	-4.0388**	0.6354**	-1.6219**	------	26.44	61.3
sqrt(TWD)	HC	PFI	Auto	-4.7949	-0.01881	0.04575**	-0.02313	------	1.379	50.7
		PFI	Manual	3.4766	0.06292	0.02025	-0.06636	------	1.696	91.0
		Carb	Auto	-1.4267	-0.2772**	0.05709**	-0.03091	------	1.353	67.6
		Carb	Manual	6.4887	-0.2508	0.03988**	-0.05128	------	1.377	52.5
		TBI	Auto	1.0814	-0.3343**	0.05810**	-0.09646**	------	1.462	59.3
	MtBE	PFI	Auto	-1.7513	0.04224	0.02285**	0.01580	------	1.314	39.6
		PFI	Manual	6.8326	-0.07759	0.005023	-0.04338	------	1.443	92.9
		Carb	Auto	-17.057	1.7429**	0.1164**	0.02050	-0.008929**	1.184	71.1
		Carb	Manual	23.347	-2.1458	-0.04476	-0.05952	0.009642	1.333	63.2
		TBI	Auto	-15.542	2.0347**	0.1239**	-0.05183*	-0.01051**	1.391	49.3
	EtOH	PFI	Auto	3.1756	-0.1544	0.03372**	-0.1014**	------	1.653	58.5
		PFI	Manual	6.7037	-0.3842**	0.03960**	-0.1295**	------	1.403	95.1
		Carb	Auto	7.3713	-0.1369	0.02786**	-0.08644**	------	1.483	69.7
		Carb	Manual	6.0386	0.2342	0.03693**	-0.1027	------	1.731	57.8
		TBI	Auto	4.6546	-0.2953**	0.04381**	-0.09425**	------	1.749	62.2

* Coefficient Significant at 90%

** Coefficient Significant at 95%

TABLE 6

Regression Coefficients Using T10

Variable	Fuel Type	Fuel System	Trans-mission	Average Intercept	T10	T50	Temp	T10xT50	Root MSE	R-Sq
TWD	HC	PFI	Auto	-72.846	0.08823	0.3840**	-0.08406	-----	12.39	47.9
		PFI	Manual	36.534	-0.1594	0.5306	-1.9204	-----	30.71	86.6
		Carb	Auto	-154.62	0.5131**	0.7634**	-0.5060	-----	22.26	60.1
		Carb	Manual	-115.30	0.8268	0.8007*	-1.1197	-----	32.94	51.1
		TBI	Auto	-152.51	0.7217**	0.7274**	-1.2361**	-----	21.79	56.7
	MtBE	PFI	Auto	-14.035	-0.03848	0.1555*	0.1120	-----	10.26	34.6
		PFI	Manual	6.6493	0.3418	0.07998	-0.4875	-----	28.45	84.9
		Carb	Auto	520.93	-4.5305**	-2.5346*	0.4090	0.02354**	16.77	67.2
		Carb	Manual	-762.47	6.1048	4.1759	-1.4653	-0.02692	27.45	60.4
		TBI	Auto	525.31	-4.1688**	-2.3585*	-0.6059*	0.02146**	17.91	46.0
	EtOH	PFI	Auto	-54.126	0.3521	0.3324**	-0.8469**	-----	19.50	49.1
		PFI	Manual	-179.42	1.4608	0.6689*	-2.0962*	-----	32.88	88.8
		Carb	Auto	-38.503	0.6731**	0.3590**	-1.1750**	-----	19.75	67.2
		Carb	Manual	137.11	-0.7071	0.9129**	-2.3621	-----	39.25	57.7
		TBI	Auto	-131.72	1.1563**	0.5276**	-1.6510**	-----	25.70	63.4
sqrt(TWD)	HC	PFI	Auto	-5.7509	0.007316	0.04537**	-0.02487	-----	1.375	51.0
		PFI	Manual	5.2715	-0.01083	0.02127	-0.06776	-----	1.693	91.0
		Carb	Auto	-7.6783	0.03994**	0.05233**	-0.03807	-----	1.357	67.4
		Carb	Manual	0.7660	0.03310	0.03452*	-0.04152	-----	1.383	52.1
		TBI	Auto	-7.1565	0.05008**	0.05286**	-0.09730**	-----	1.445	60.3
	MtBE	PFI	Auto	-0.7321	-0.004769	0.02289**	0.01471	-----	1.316	39.5
		PFI	Manual	4.3420	0.01457	0.004693	-0.04290	-----	1.439	92.9
		Carb	Auto	34.115	-0.2797*	-0.1458	0.01813	0.001437*	1.181	71.3
		Carb	Manual	-44.166	0.3821	0.2590	-0.05914	-0.001720	1.331	63.3
		TBI	Auto	43.974	-0.3251**	-0.1832*	-0.05391*	0.001680**	1.388	49.6
	EtOH	PFI	Auto	-3.2781	0.04850*	0.02898**	-0.1041**	-----	1.626	59.9
		PFI	Manual	-6.9308	0.09082**	0.03213**	-0.1253**	-----	1.401	95.1
		Carb	Auto	1.4712	0.04400**	0.02359**	-0.08744**	-----	1.398	67.6
		Carb	Manual	11.645	-0.03403	0.03952**	-0.09613	-----	1.787	55.0
		TBI	Auto	-6.8218	0.08227**	0.03624**	-0.09592**	-----	1.698	64.4

* Coefficient Significant at 90%

** Coefficient Significant at 95%

TABLE 7

Mean TWD, Mean Square Root TWD, and YVF by Fuel
Normalized to 40°F Test Temperature

Fuel Type	Fuel	RVP	T_{10}	T_{50}	T_{90}	Mean TWD	YVF 1	YVF 2	Square Root Mean TWD	Square Root YVF 1	Square Root YVF 2
HC	1	11.1	113.7	204.3	335.3	26.2	88.7	151.7	4.844	7.207	10.910
HC	2	6.5	145.0	198.6	336.3	34.9	94.8	161.3	5.473	7.509	11.430
HC	3	11.1	119.1	246.4	332.9	53.5	111.6	175.8	7.037	8.961	12.727
HC	4	6.7	146.9	241.1	342.7	64.8	117.5	184.1	7.796	9.256	13.180
HC	5	9.0	121.5	221.9	336.6	38.3	102.5	164.0	5.778	8.186	11.802
MTBE	6	10.9	115.3	181.0	326.4	33.0	76.5	140.2	5 309	6.260	10.014
MTBE	7	6.8	138.7	181.1	328.4	27.3	87.7	149.7	4.897	6.745	10.578
MTBE	8	11.0	113.4	217.3	324.1	37.3	96.0	158.4	5.844	7.760	11.424
MTBE	9	6.7	141.7	219.9	329.9	48.5	106.0	171.0	6.652	8.373	12.205
MTBE	10	8.6	126.7	198.9	328.0	27.3	90.8	154.1	4.895	7.275	11.005
EtOH	11	11.3	115.7	170.4	332.1	33.8	69.9	134.9	5.228	5.772	9.599
EtOH	12	6.8	134.1	185.4	331.4	47.4	87.0	150.0	6.528	6.924	10.640
EtOH	13	11.3	119.6	234.1	328.3	60.1	104.5	169.6	7.344	8.425	12.246
EtOH	14	6.9	140.0	234.4	335.9	78.9	113.4	177.9	8.595	8.953	12.746
EtOH	15	8.8	125.7	208.3	331.9	36.3	95.5	158.6	5.405	7.643	11.357

TABLE 8

Average Fuel Tank Temperature Increases (°F)
15-Mile Warmup

	Over Initial Tank Temperature		Over Ambient Temperature	
	Vehicle Number		Vehicle Number	
PFI	1	16 8	1	19.8
	2	21.1	2	19.9
	3	20.1	3	21.3
	4*	18.4	4	22.6
	5	18.9	5	22.5
	6	21.1	6	20.8
	7*	11.3	7	11.0
	8	15.7	8	15.7
TBI	9	20.8	9	19.0
	10	17.3	10	15.6
	11	16.5	11	17.2
	12*	21.6	12	24.2
	13	17.3	13	17.5
	14	18.1	14	18.1
	15*	16.3	15	17.1
	16	17 4	16	16.8
CARB	17	15.5	17	15.3
	18	9.3	18	9.2
	19	14.5	19	13.7
	20	14.1	20	12.7
	21	16.1	21	15.2
	22	16.5	22	15.1
	23*	16.1	23	15.3
	24*	10.7	24	10.5

* Vehicles selected for extended warmup in Phase II

TABLE 9

Average Fuel Tank Temperature Increases, (°F)
By Group

15-Mile Warmup

Group	Number Of Vehicles	Over Initial Tank Temperature	Over Ambient Temperature
Carb	8	14.04	13.33
PFI	8	17.87	19.22
TBI	8	18.28	18.46
Metal Tank	21	17.15	17.46
Plastic Tank	3	14.20	14 38

TABLE 10

Average Fuel Tank Temperature Increases (°F)
Extended (30-Mile) Warmup

Phase II Testing

Vehicle Number	Fuel System	Over Initial Tank Temperature 15-Mile	30-Mile	▲	Over Ambient Temperature 15-Mile	30-Mile	▲
4	PFI	13.7	16.9	3.2	22.3	25.5	3.2
7	PFI	10.5	13.9	3.4	11.3	14.7	3.4
12	TBI	16.2	18.8	2.6	23.4	26.5	3.1
15	TBI	12.9	15.4	2.5	17.2	19.4	2.2
23	CARB	15.0	18.3	3.3	15.3	18.6	3.3
24	CARB	9.8	11.8	2.0	11.0	13.0	2.0

TABLE 11

Rater Repeatability Cars
Total Weighted Demerits

Vehicle Number	1	2	3	4	5	6	Average Rater
25	24	32	41	133	59	90	
	22	44	20	53	70	61	
	8	49	25	57	88	33	
	41	51	31	57	81	62	
	42	38	52	64	64	14	
Average	27.4	42.8	33.8	72.8	73.2	52.0	50.33
Relative to Average Rater	0.54	0.85	0.67	1.45	1.45	1.03	
26	28	40	54	60	56	36	
	42	39	39	55	47	33	
	50	45	34	30	44	21	
	44	27	36	41	62	27	
	87	45	34	53	93	42	
Average	50.2	39.2	39.4	47.8	60.4	31.8	44.8
Relative to Average Rater	1.12	0.88	0.88	1.07	1.35	0.71	
27	71	27	50	126	89	122	
	65	92	55	102	100	54	
	56	55	31	68	39	104	
	128	51	55	107	95	25	
	118	58	67	86	98	76	
Average	87.6	56.6	51.6	97.8	84.2	76.4	75.7
Relative to Average Rater	1.16	0.75	0.68	1.29	1.11	1.01	
3-Vehicle Average Relative Severity	0.97	0.81	0.73	1.28	1.27	0.94	

TABLE 12

T_{10} AND T_{50} DEPENDENCE OF DEMERITS BY FUEL TYPE

Fuel Type	Demerits							
	Total		Cold		Warm		Idle	
	T_{10}	T_{50}	T_{10}	T_{50}	T_{10}	T_{50}	T_{10}	T_{50}
Hydrocarbon	0.45	0.63	0.35	0.51	0.04	0.02	0.05	0.09
Ethanol	0.80	1.18	0.78	0.91	0.02	0.14	0.00	0.12
MTBE	0.25	0.74	0.17	0.66	0.02	0.01	0.06	0.08

FIGURE 1

FUEL BLENDING STRATEGY

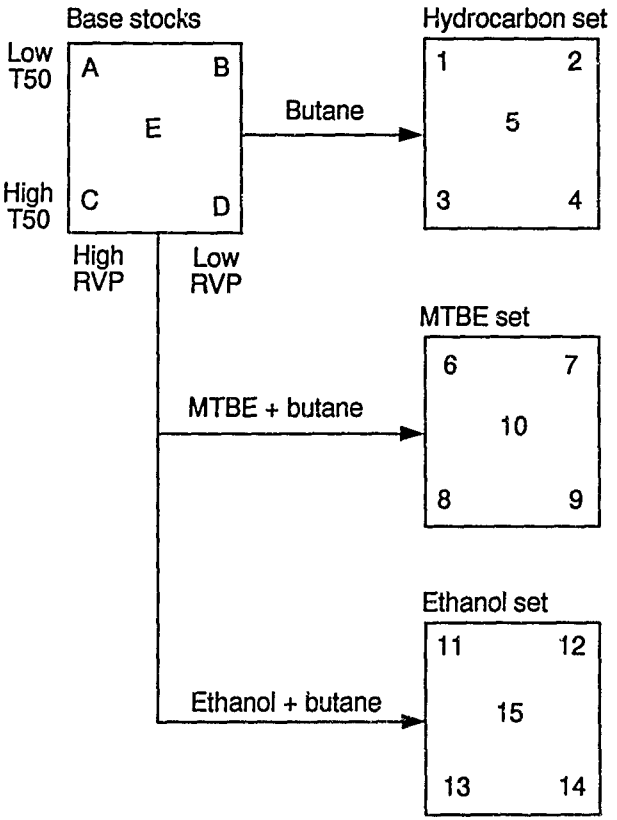


FIGURE 2

TEST SITE AND DRIVING SCHEMATIC

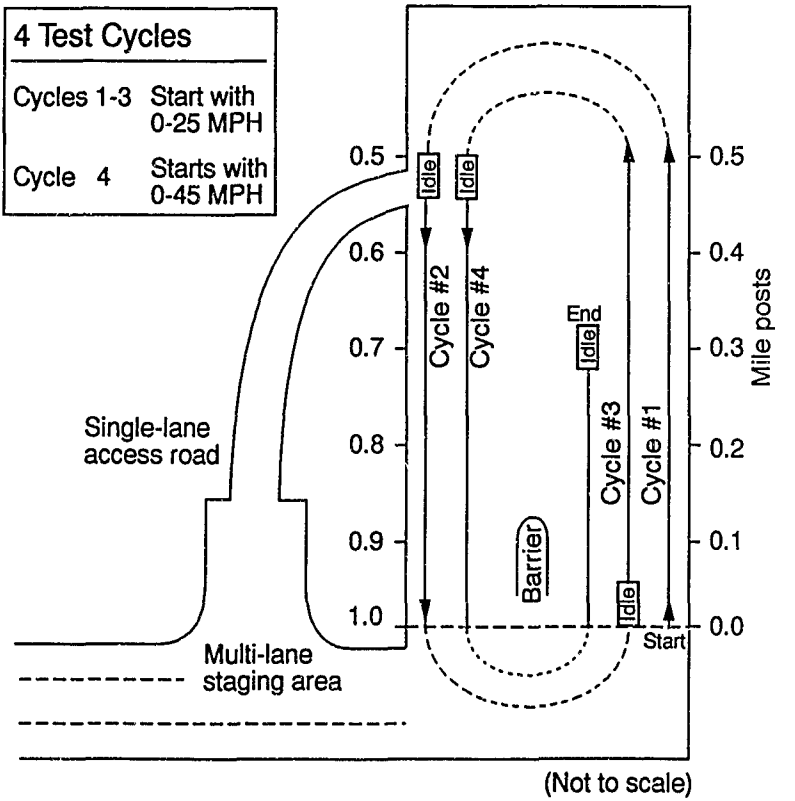


FIGURE 3

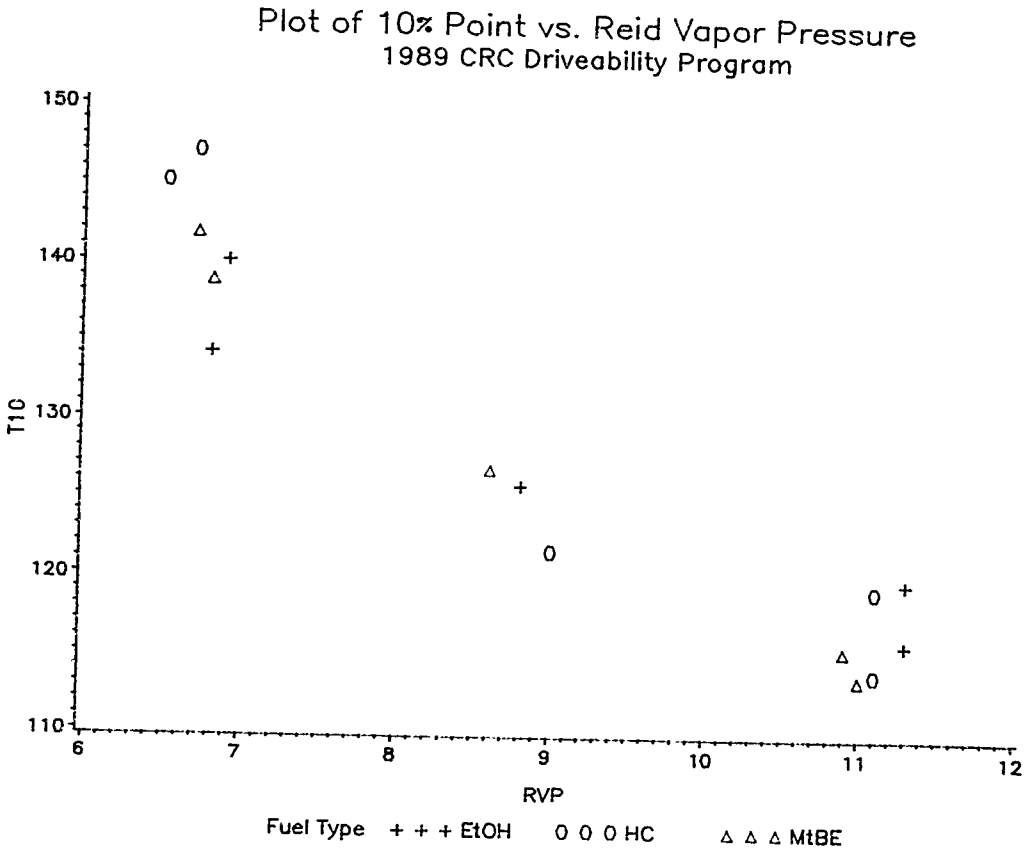

Plot of 10% Point vs. Reid Vapor Pressure
1989 CRC Driveability Program
T10
150
140
130
120
110
6
7
8
9
10
11
12
RVP
Fuel Type + + + EtOH 0 0 0 HC Δ Δ Δ MtBE

FIGURE 4

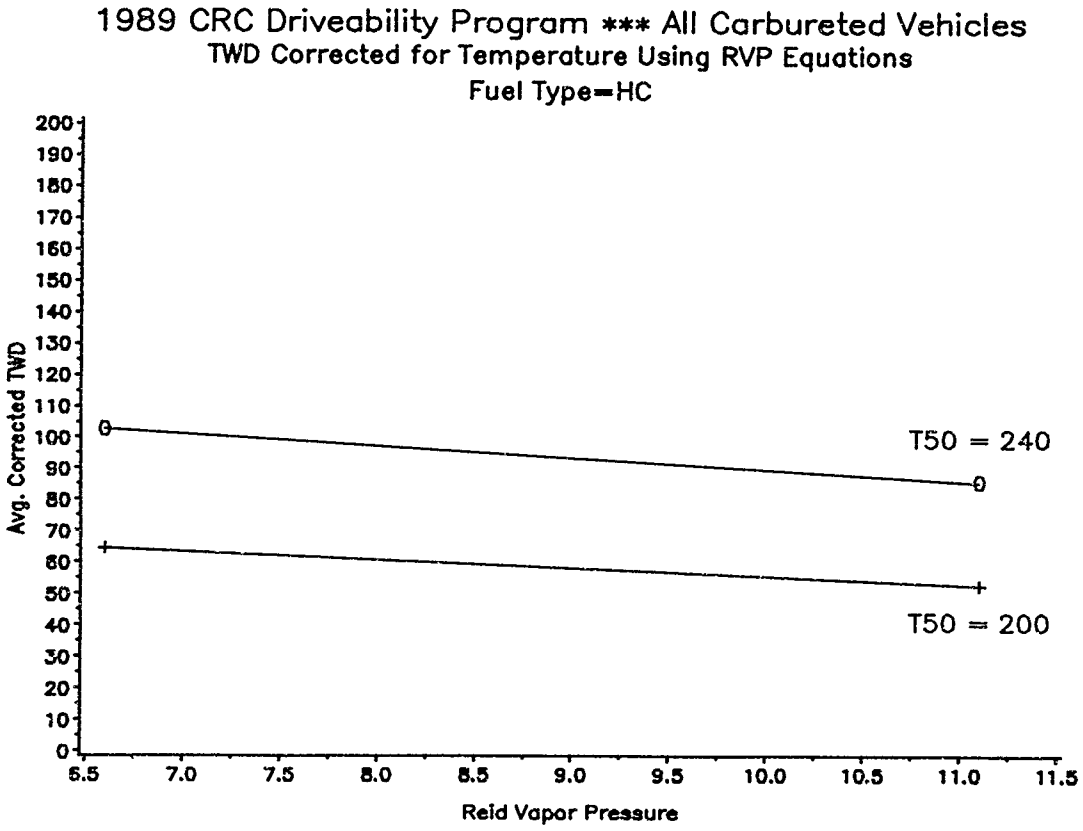

1989 CRC Driveability Program *** All Carbureted Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 240
T50 = 200

FIGURE 5

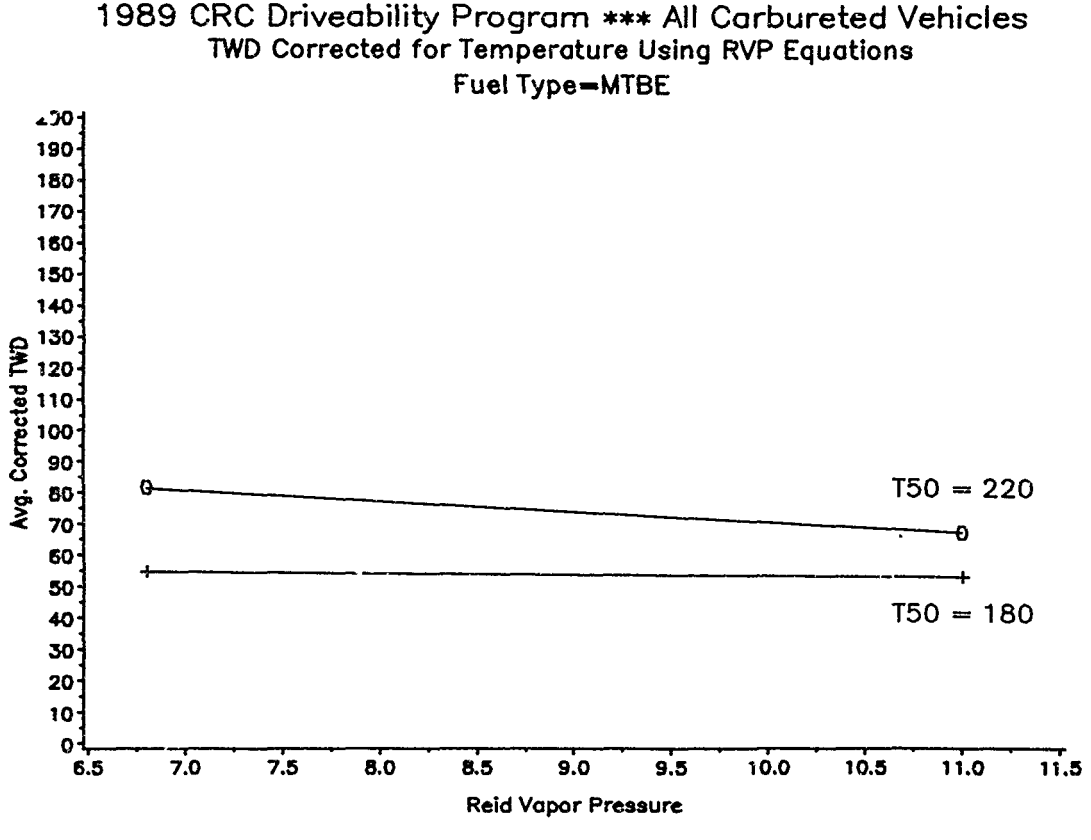

1989 CRC Driveability Program *** All Carbureted Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE 6

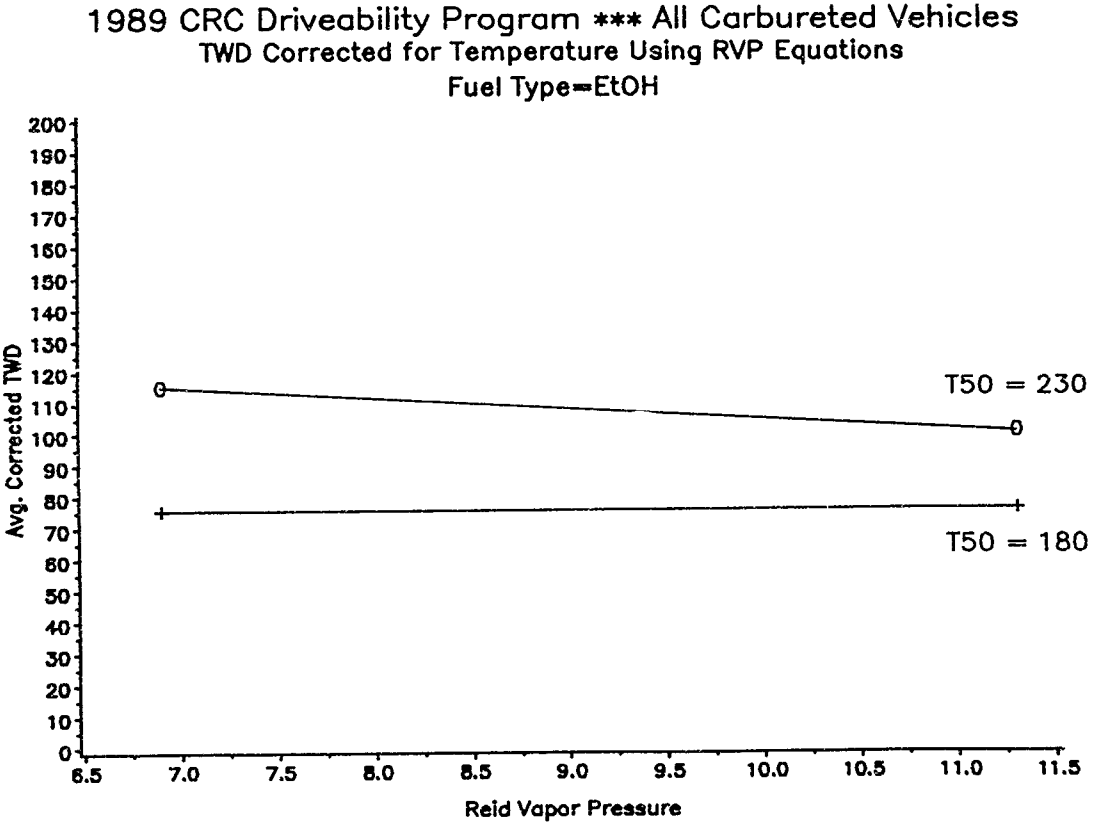

1989 CRC Driveability Program *** All Carbureted Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
T50 = 230
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE 7

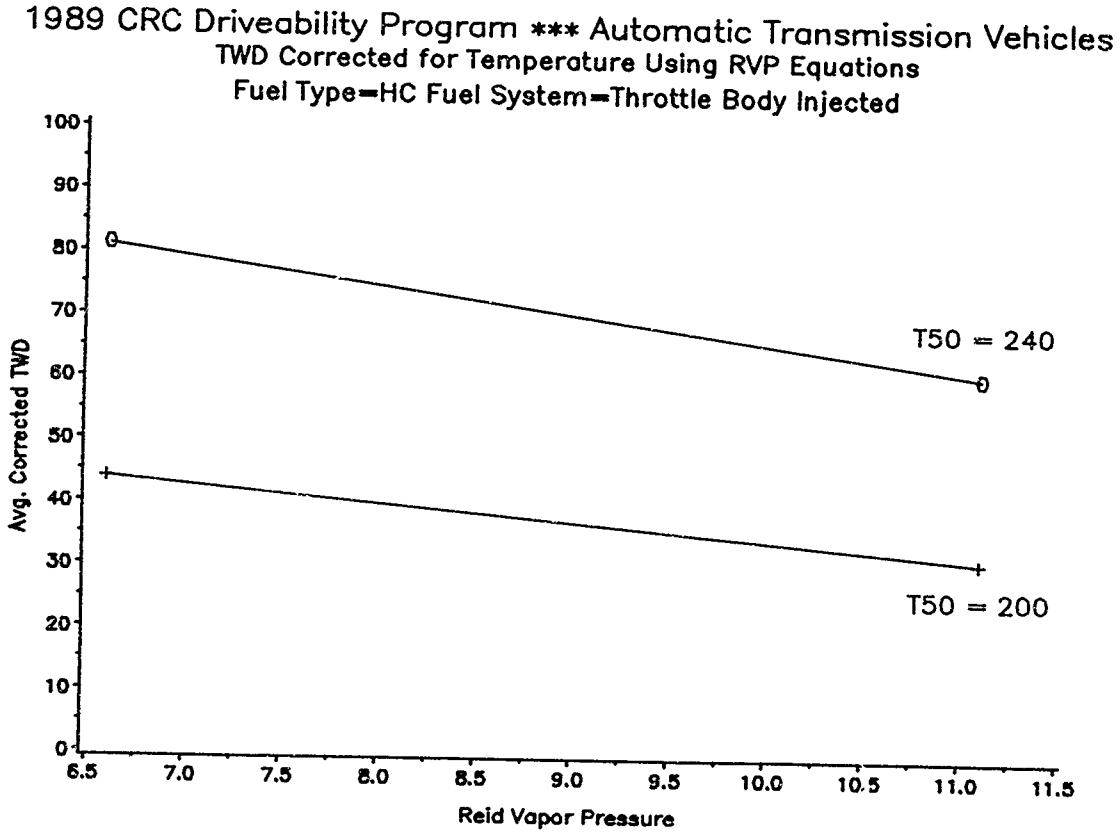

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Throttle Body Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 240
T50 = 200

FIGURE 8

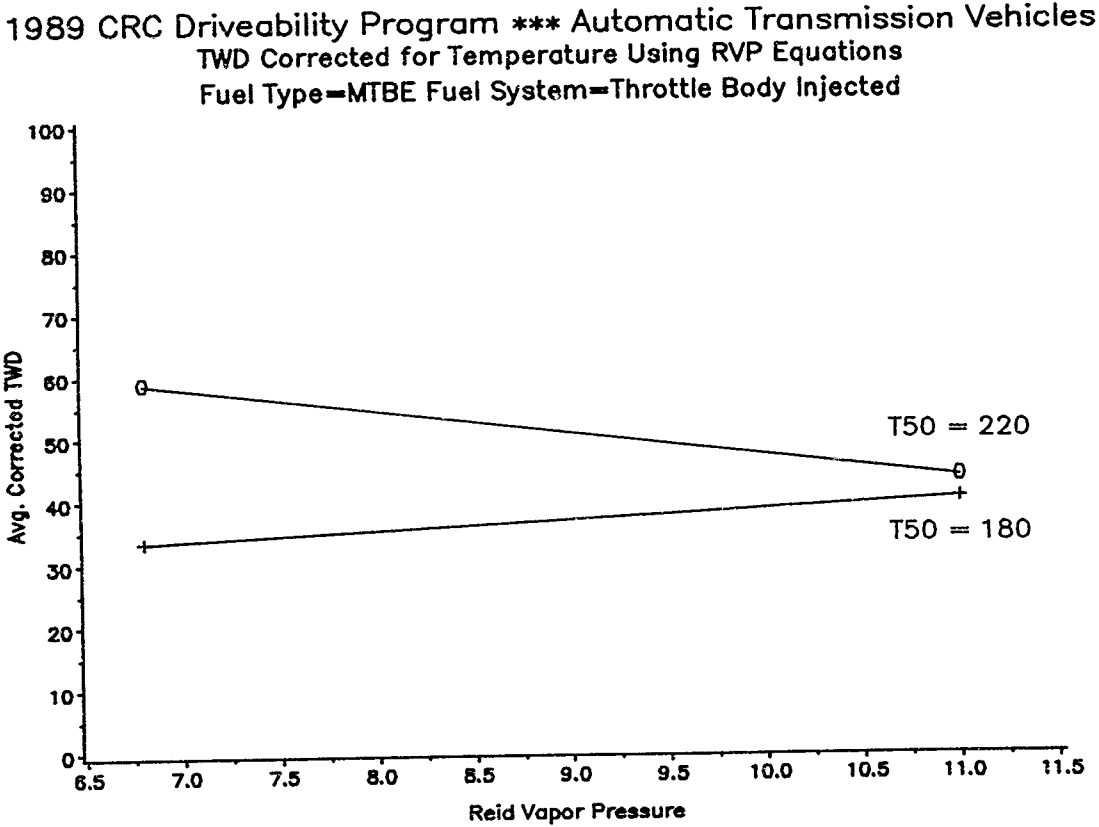

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE Fuel System=Throttle Body Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE 9

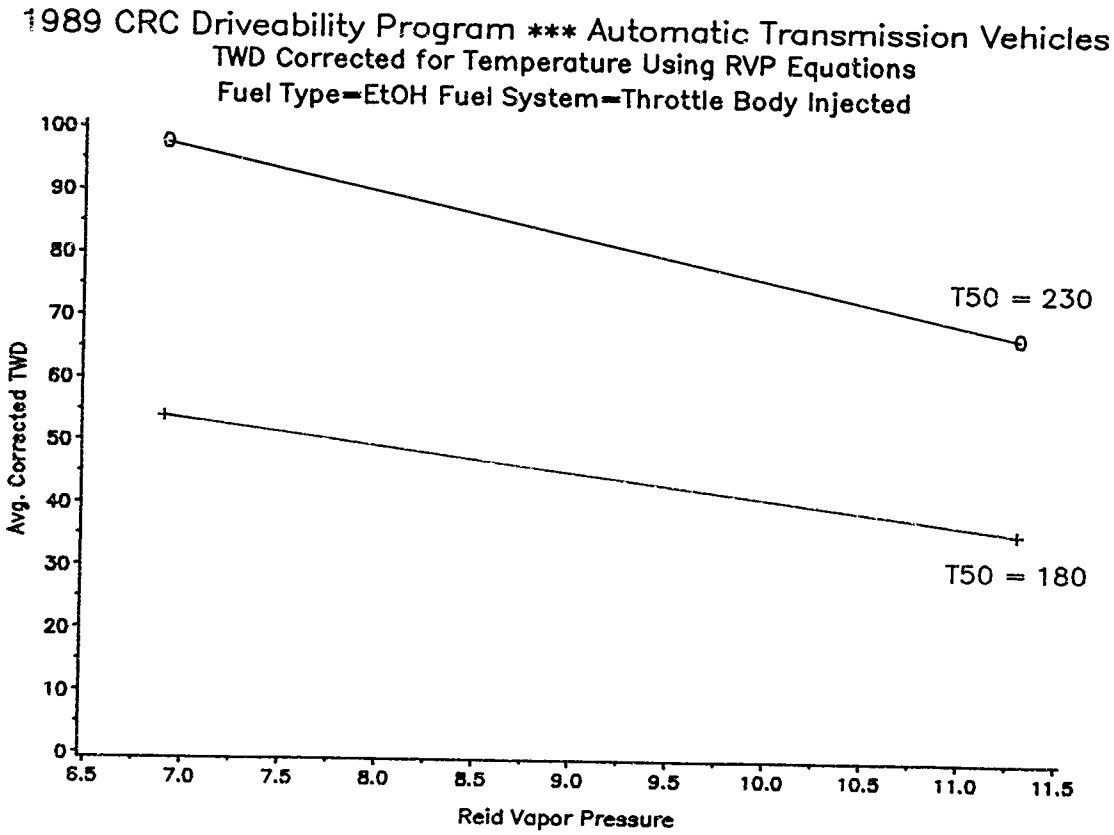

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Throttle Body Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 230
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE 10

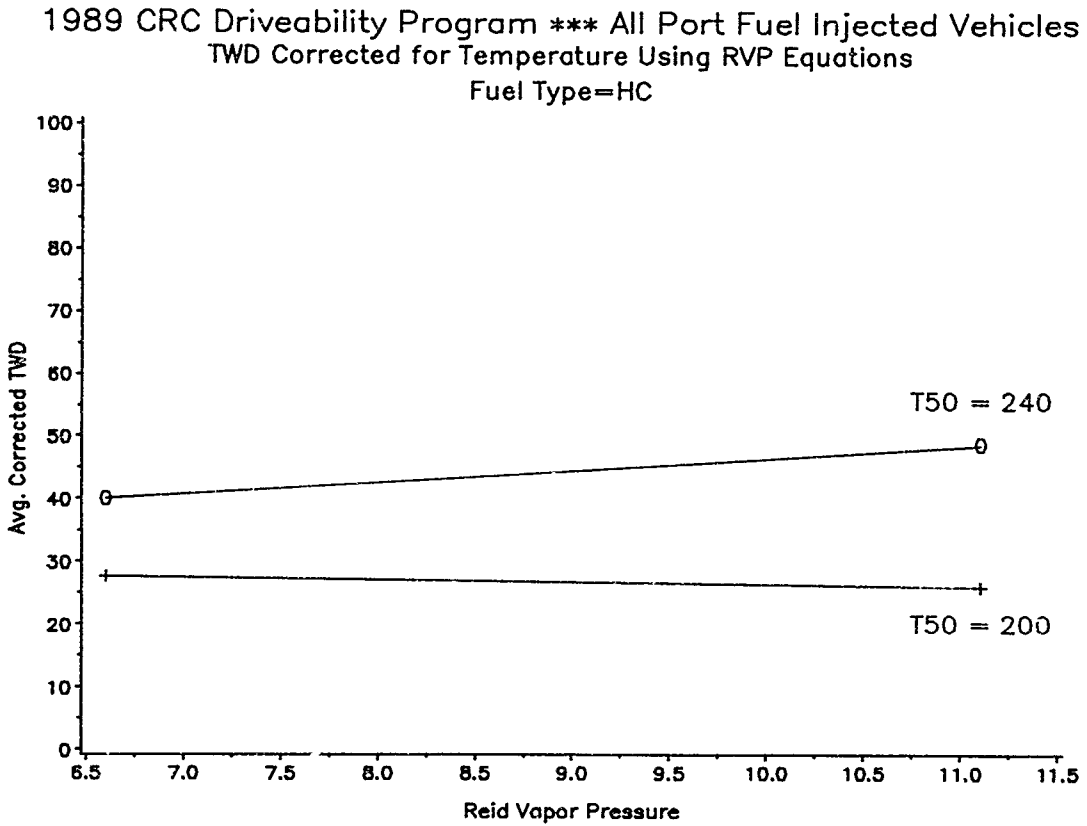

1989 CRC Driveability Program *** All Port Fuel Injected Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 240
T50 = 200
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE 11

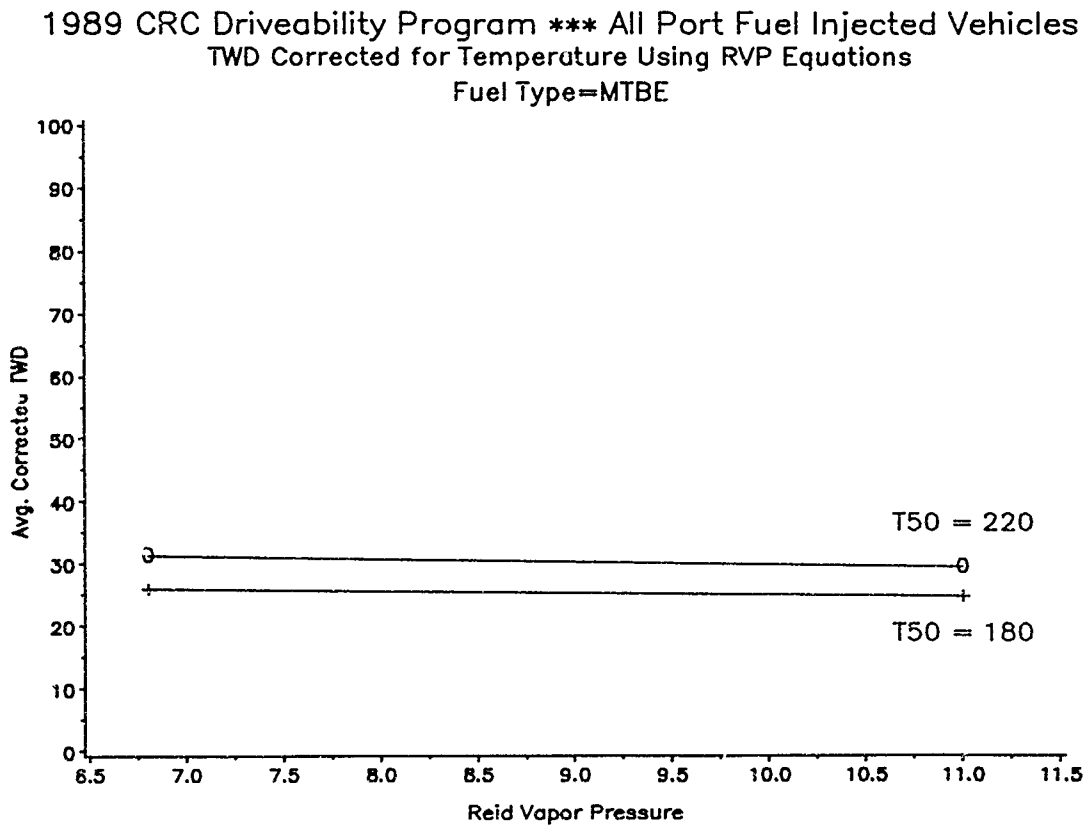

1989 CRC Driveability Program *** All Port Fuel Injected Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE 12

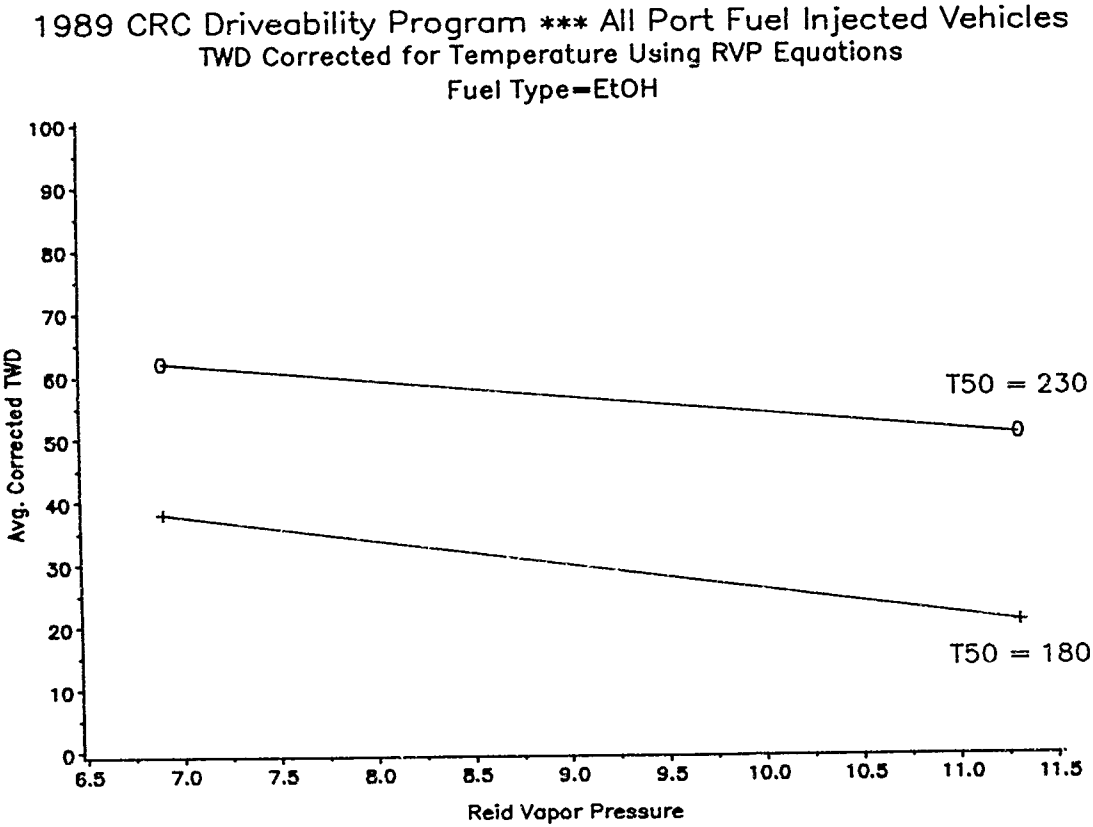
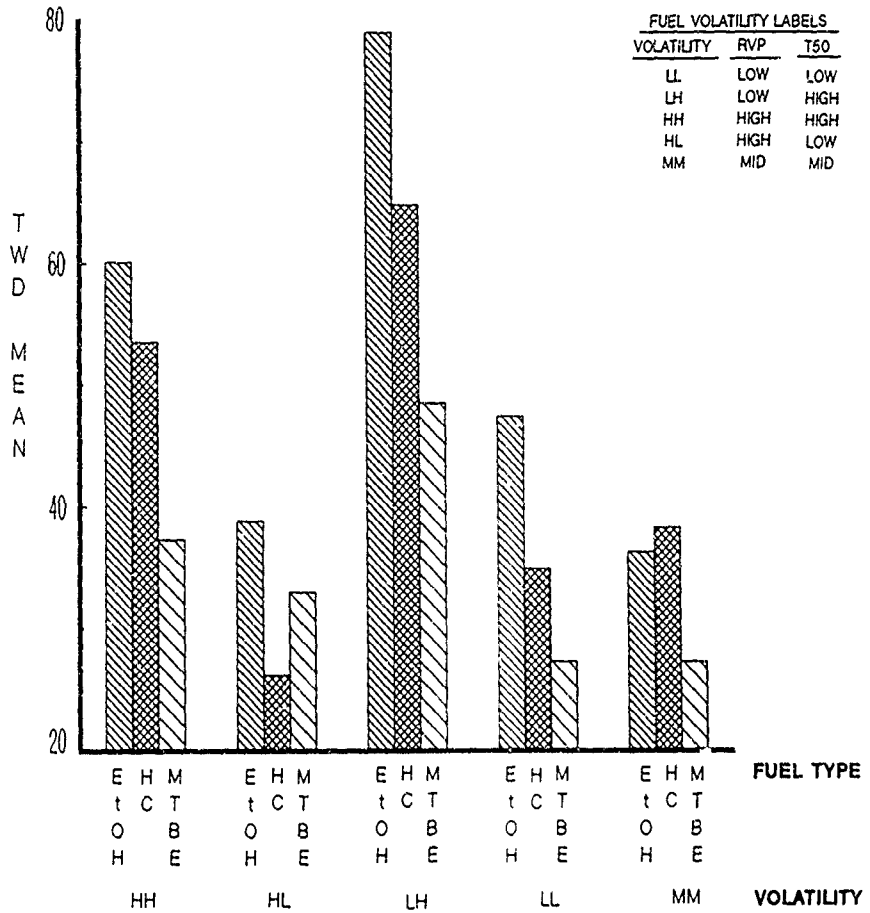

1989 CRC Driveability Program *** All Port Fuel Injected Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 230
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE 13



DRIVEABILITY DEMERITS BY FUEL TYPE AND VOLATILITY LEVEL
NORMALIZED TO 40 F

FIGURE 14

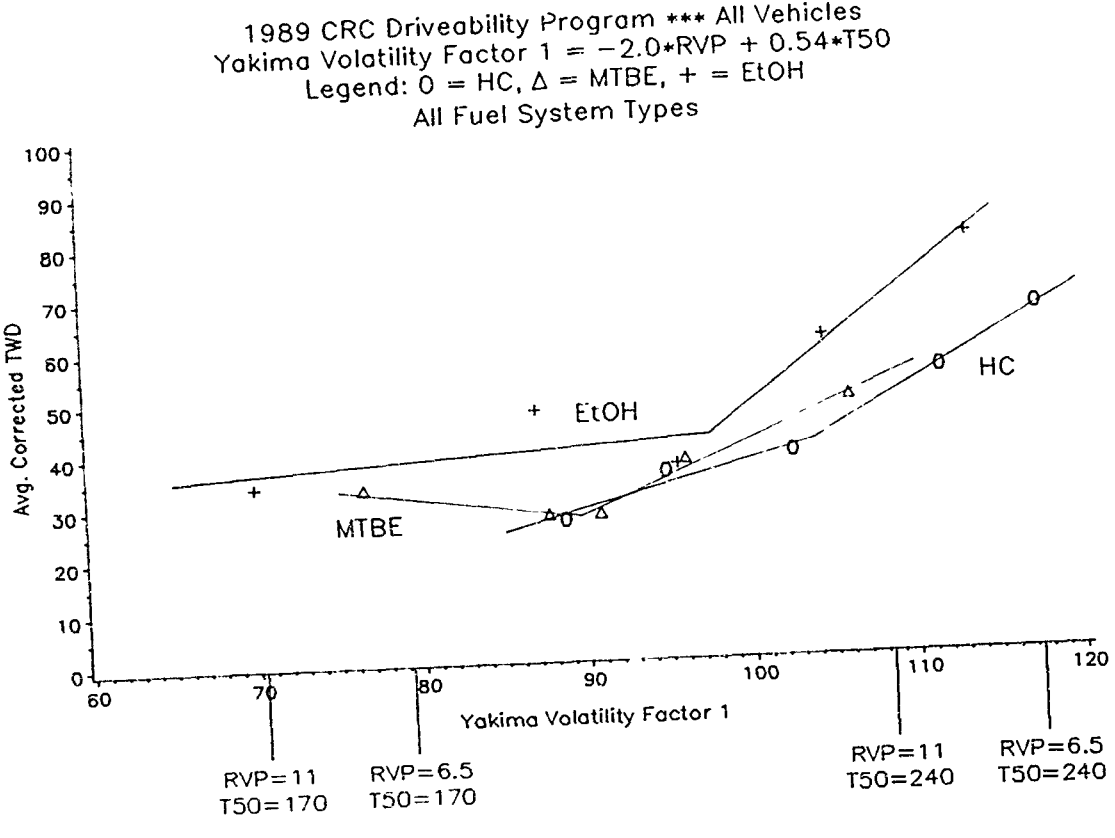
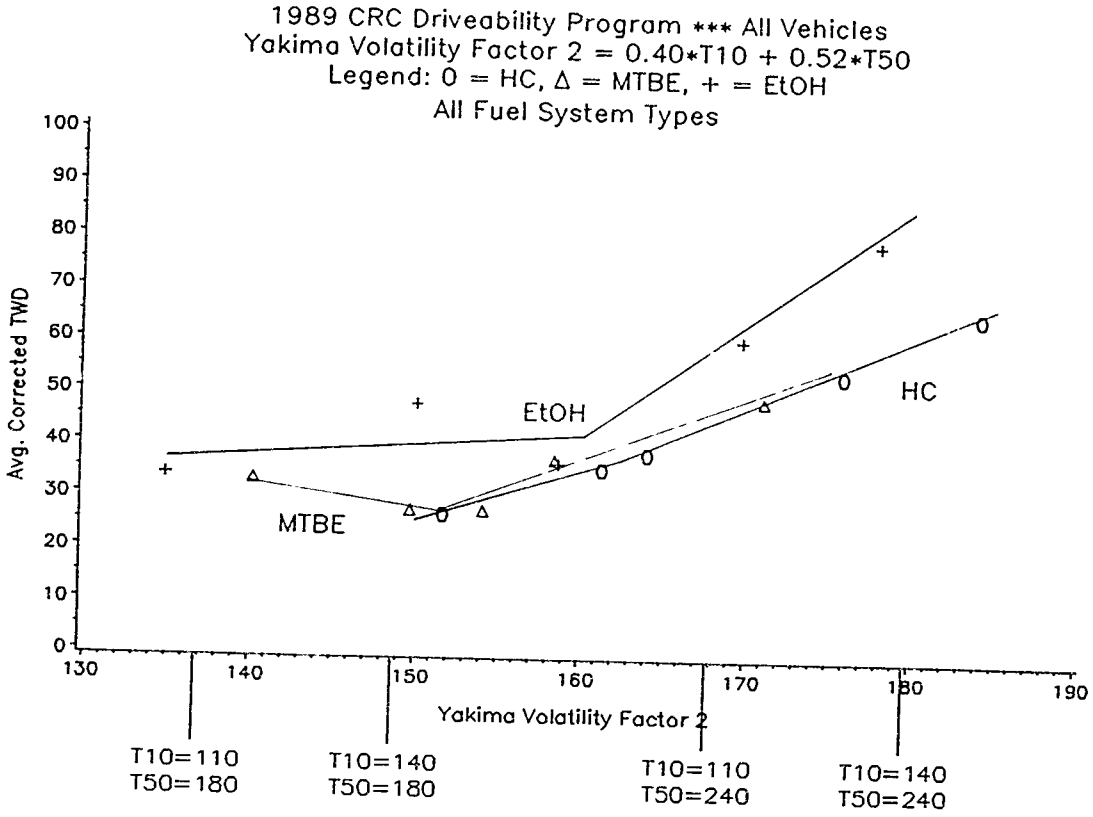

1989 CRC Driveability Program *** All Vehicles
Yakima Volatility Factor 1 = −2.0*RVP + 0.54*T50
Legend: 0 = HC, Δ = MTBE, + = EtOH
All Fuel System Types
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
EtOH
MTBE
HC
60
70
80
90
100
110
120
Yakima Volatility Factor 1
RVP=11
T50=170
RVP=6.5
T50=170
RVP=11
T50=240
RVP=6.5
T50=240

FIGURE 15


1989 CRC Driveability Program *** All Vehicles
Yakima Volatility Factor 2 = 0.40*T10 + 0.52*T50
Legend: 0 = HC, Δ = MTBE, + = EtOH
All Fuel System Types
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
EtOH
HC
MTBE
130
140
150
160
170
180
190
Yakima Volatility Factor 2
T10=110
T50=180
T10=140
T50=180
T10=110
T50=240
T10=140
T50=240

APPENDIX A

MEMBERSHIP

OF THE

1989 CRC DRIVEABILITY ANALYSIS PANEL

MEMBERSHIP OF THE

1989 CRC DRIVEABILITY ANALYSIS PANEL

NAME	AFFILIATION
R. M. Reuter, Leader	Texaco Inc.
D. A. Barker	Shell Development Company
P. J. Costello	Mobil Research & Development Corporation
J. P Graham	Chevron Research & Technology Company
S. W. Jorgensen	General Motors Research Laboratories
L. G. Korducki	Texaco, Inc.
J. H. Steury	Amoco Oil Company
C. T. Valade	Chrysler Motors

APPENDIX B

PARTICIPANTS IN THE
1989 CRC DRIVEABILITY PROGRAM

PARTICIPANTS IN THE

1989 CRC INTERMEDIATE-TEMPERATURE DRIVEABILITY PROGRAM

NAME	AFFILIATION
Bob Reuter, Leader	Texaco Inc.
Harold "Archie" Archibald	BP Oil
Dave Barker	Shell Development Company
John Baudino	AutoResearch Laboratories, Inc.
Andy Buczynsky	Sun Refining & Marketing Company
George Budzinski	BP Oil
Randy Chevalier	Chevron Research & Technology Company
Pat Costello	Mobil Research & Development Corporation
Jimmie Douglass	Shell Development Company
Jean Doyon	Shell Canada
Beth Evans	Coordinating Research Council, Inc.
John Graham	Chevron Research & Technology Company
Ken Hennessy	AutoResearch Laboratories, Inc.
Bill Honchar	PetroCanada
Roy Hoppe	Shell Canada
Scott Jorgensen	General Motors Research Laboratories
Larry McGuire	Chrysler Motors
Andy Mick	General Motors Research Laboratories
Gary Phillips	Unocal
Mike Ragomo	Mobil Research & Development Corporation
Doug Rathe	Shell Development Company
Jim Reid	Petro Canada
Steve Simms	Amoco Oil Company
Chuck Valade	Chrysler Motors

APPENDIX C

1989 CRC PROGRAM ON THE EFFECT OF VOLATILITY ON DRIVEABILITY AT INTERMEDIATE AMBIENT TEMPERATURES

COORDINATING RESEARCH COUNCIL
INCORPORATED
219 PERIMETER CENTER PARKWAY
ATLANTA GEORGIA 30346
(404) 396-3400

Not to be Published

1989 CRC PROGRAM
ON THE EFFECT OF VOLATILITY
ON DRIVEABILITY AT INTERMEDIATE AMBIENT TEMPERATURES

Prepared by the

CRC-Automotive Volatility Group

May 1989

1989 CPC PROGRAM ON THE EFFECT OF

VOLATILITY ON DRIVEABILITY AT INTERMEDIATE AMBIENT TEMPERATURES

Objective

To determine the independent effects of front-end volatility (RVP) and mid-range volatility (T_{50}) on cold start and warm-up driveability of late model cars at intermediate ambient temperatures (30°F-50°F). Volatility ranges investigated will be those that may be required of future summer-time fuels and will include both hydrocarbon-only and hydrocarbon-oxygenate blends.

Background

Current regulation proposals would limit summertime fuel front-end volatility by limiting fuel RVP to values considerably less than current commercial practice. There is some concern that such low vapor pressure fuels, particularly if long lead times are required to insure the products meet requirement at the beginning of the regulation period, may suffer degraded driveability.

Test Temperature/Timing/Location

Target test temperatures will be 30°F-50°F representing the general low range of ambient temperatures which might be associated with use of low summertime RVP fuels of either Class A, B, or C fuels. The outlined program will take six weeks to accomplish. Since the fall of the year is likely to provide longer time periods of stable weather conditions with minimum rainfall, tentative program dates would be from October 9, 1989, through November 18, 1989. Preliminary indications are that the Renegade Raceway drag strip in Yakima, Washington, will be suitable for our test needs. The drag strip is a paved, 3900-foot-by 60-foot asphalt track with an adjacent staging area. Additional facilities such as rest room, electrical power, potential fuel storage area, and access to public roads for warm-up appear suitable. In addition, insurance coverage seems to satisfy CRC requirements. A local facts sheet and 30-year average weather conditions for the area are included as Tables C-1 and C-2, respectively.

Test Procedure

The CRC Cold-Start and Warmup Driveability Procedure will be used and is attached as Attachment 1.

Vehicles

Twenty-four late-model vehicles will be needed for the main test program, as specified in Table C-3. These will be a mix of carbureted, PFI, and TBI fuel delivery systems. It is anticipated that the PFI and TBI cars will be 1988-1989 production models. Some difficulty may be encountered in obtaining new model vehicles with carbureted fuel systems. In this case, pre-1988 model vehicles will be used to complete the fleet makeup. All vehicles will be of closed-loop design and will have automatic transmissions.

Although it would be desirable to maintain the same driver-raters for the duration of the program which would preclude the need for rater adjustments, this may not be possible. Therefore, three additional vehicles will be provided for use in developing driver-rater correction factors.

All vehicles will be equipped with a manifold vacuum tap and fuel tank drains to facilitate fuel changeovers.

Fuels

There will be three test fuel compositions; a hydrocarbon-only fuel series, a 15 vol.% MtBE fuel series, and a 10 vol.% EtOH fuel series. In each fuel series, there will be five individual test fuels. The five fuels in each series will consist of a 2 x 2 square design of high and low front-end volatility and high and low mid-range volatility, plus a center-point fuel. For ease of blending and to maintain the desired separation between test fuel properties, each of the fifteen test fuels will be made from five common base fuels designated as fuels A through E. Table C-4 shows the five hydrocarbon blend stocks and the blend specifications for the fifteen test fuels.

TABLE C-1

Facts
About
Yakima, Washington
and the
Yakima Valley

POPULATION	1960	1970	1980	1986 (estimates)
Yakima	43 284	45 588	49 826	49 590
Urban Area	65 000	72 ,00	86 788	90 000
County	145 112	14, 212	172 508	183,600

RETAIL SALES	1960	1970	1980	1985
City	$105 004 000	$158 311 000	$440 656 000	$511 828 000
County	$183 587 000	$253 923 000	$719 343 000	$888 781 000

EFFECTIVE BUYING INCOME PER MEDIAN HOUSEHOLD (E B I)	1970	1980	1985
City	$8 697	$15 578	$17 492
County	$9 358	$16 189	$18 578

YAKIMA SUNSHINE SCHEDULE

Month	Min Temp	Max Temp	Precipitation
January	18 6	36 4	1 33
February	25 2	46 1	0 78
March	28 8	54 8	0 58
April	34 8	64 1	0 51
May	42 6	73 1	0 55
June	49 3	79 7	0 73
July	53 3	88 1	0 16
August	51 2	85 9	0 25
September	44 3	78 3	0 31
October	35 4	64 7	0 58
November	28 3	48 5	1 07
December	23 5	39 1	1 15

Average of 300 days of sunshine annually normal total of 8 00 inches of precipitation Average length of growing season is 195 days

YAKIMA GEOGRAPHY

Yakima county seat of Yakima County latitude 46° 34' north longitude 120° 32 west and with an altitude of 1,068 feet is located in Central Washington an area of rich volcanic soil Yakima City is 13 square miles Yakima County is 4,275 square miles second largest land area in Washington State and sixth largest population area in Washington State

145 miles southeast of Seattle
201 miles southwest of Spokane
150 miles southwest of Grand Coulee Dam
185 miles northeast of Portland
146 miles south of the Canadian border
60 miles from the heart of the million acre Columbia Basin
91 miles north of the Washington Oregon border

Published by the Greater Yakima Chamber of Commerce

Post Office Box 1490 — 10 North 8th Street
Yakima, Washington 98907 (509) 248-2021

TABLE C-2

CLIMATOGRAPHY OF THE UNITED STATES NO 81

DAILY NORMALS OF TEMPERATURE, HEATING AND COOLING DEGREE DAYS AND PRECIPITATION 1951-80

459465 YAKIMA WSO LATITUDE 46 34N LONGITUDE 120 32W ELEVATION 1064 FT.

	SEPTEMBER						OCTOBER						NOVEMBER					
	TEMPERATURE			DEG	DAY		TEMPERATURE			DEG	DAY		TEMPERATURE			DEG	DAY	
DAILY	MAX	MIN	AVG	HDD	CDD	PRECIP	MAX	MIN	AVG	HDD	CDD	PRECIP	MAX	MIN	AVG	HDD	CDD	PRECIP
1	82	48	65	3	3	02	72	39	56	9	0	01	55	31	43	22	0	02
2	82	48	65	3	3	02	71	39	55	10	0	01	55	31	43	22	0	02
3	82	48	65	3	3	02	71	39	55	10	0	01	54	30	42	23	0	03
4	81	48	64	3	2	01	71	39	55	10	0	01	53	30	42	23	0	03
5	81	47	64	3	2	01	70	38	54	11	0	01	53	30	42	23	0	03
6	81	47	64	3	2	01	69	38	54	11	0	01	52	30	41	24	0	03
7	80	47	64	3	2	01	69	38	53	12	0	01	52	30	41	24	0	03
8	80	47	63	4	2	01	69	37	53	12	0	01	51	29	40	25	0	03
9	80	46	63	4	2	01	68	37	53	12	0	01	51	29	40	25	0	03
10	79	46	63	4	2	01	68	37	52	13	0	01	50	29	40	25	0	03
11	79	46	62	4	1	01	67	36	52	13	0	01	50	29	39	26	0	03
12	79	45	62	4	1	01	67	36	52	13	0	01	49	29	39	26	0	03
13	79	45	62	4	1	01	66	36	51	14	0	01	49	28	39	26	0	03
14	78	45	61	5	1	01	66	36	51	14	0	01	48	28	38	27	0	03
15	78	45	61	5	1	01	65	35	50	15	0	01	48	28	38	27	0	03
16	78	44	61	5	1	01	65	35	50	15	0	02	47	28	38	27	0	03
17	77	44	61	5	1	01	64	35	50	15	0	02	47	28	37	28	0	03
18	77	44	60	6	1	01	64	34	49	16	0	02	47	28	37	28	0	03
19	76	43	60	6	1	01	63	34	49	16	0	02	46	28	37	28	0	03
20	76	43	60	6	1	01	63	34	48	17	0	02	46	27	37	28	0	03
21	76	43	59	7	*	01	62	34	48	17	0	02	45	27	36	29	0	03
22	75	42	59	7	*	01	62	33	48	17	0	02	45	27	36	29	0	04
23	75	42	59	7	*	01	61	33	47	18	0	02	45	27	36	29	0	04
24	75	42	58	7	*	01	60	33	47	18	0	02	44	27	36	29	0	04
25	74	41	58	8	*	01	60	33	46	19	0	02	44	27	35	30	0	04
26	74	41	58	8	*	01	59	32	46	19	0	02	44	27	35	30	0	04
27	73	41	57	8	*	01	59	32	45	20	0	02	44	26	35	30	0	04
28	73	41	57	8	*	01	58	32	45	20	0	02	43	26	35	30	0	04
29	73	40	56	9	0	01	57	32	45	20	0	02	43	26	35	30	0	04
30	72	40	56	9	0	01	57	31	44	21	0	02	43	26	34	31	0	04
31							56	31	44	21	0	02						
MONTHLY	77 5	44 3	60 9	161	38	33	64 5	35 1	49 9	468	0	47	48 1	28 2	38 2	804	0	93
AUTUMN	63 4	35 9	49 7	1433	38	1 77						ANNUAL	63 0	36 4	49 7	6031	484	7 98

NOTES

DEGREE DAYS BASE TEMPERATURE = 65 DEG F. TEMPERATURE UNITS = DEG F. PRECIPITATION UNITS = INCHES. * = LESS THAN 1 BUT GREATER THAN 0

THE DAILY VALUES PRESENTED IN THESE TABLES ARE NOT SIMPLE MEANS OF OBSERVED DAILY VALUES. THEY ARE INTERPOLATED FROM THE MUCH LESS VARIABLE MONTHLY NORMALS BY USE OF THE NATURAL SPLINE FUNCTION. IN LEAP YEARS USE THE FEBRUARY 28TH VALUES FOR THE 29TH AND ADJUST THE DEGREE DAY AND PRECIPITATION MONTHLY TOTALS ACCORDINGLY. DAILY PRECIPITATION NORMALS WERE ALSO COMPUTED USING THE NATURAL SPLINE FUNCTION AND DO NOT EXHIBIT THE TYPICAL DAILY RANDOM PATTERNS. HOWEVER, THEY MAY BE USED TO COMPUTE NORMAL PRECIPITATION OVER TIME INTERVALS

TABLE C-3

TEST VEHICLES

MAKE	MODEL	DISPLACEMENT, LITERS	FUEL SYSTEM
Nissan	Stanza or Maxima	2.0 or 3.0	PFI
Chrysler	New Yorker Landau	3.0	PFI
Oldsmobile	Cutlass Calais	2.3	PFI
Chevrolet	Celebrity	2.8	PFI
Buick	Park Avenue	3.8	PFI
Ford	Mark VII	5.0	PFI
Ford	Aerostar	3.0	PFI
Ford	Bronco	4.9	PFI
Dodge	Shadow	2.2	TBI
Chevrolet	Cavalier	2.0	TBI
Eagle	Premier LX	2.5	TBI
Honda	Civic	1.5	TBI
Ford	Escort	1.9	TBI
Ford	Taurus	2.5	TBI
Dodge	Van	5.2	TBI
Plymouth	Acclaim	2.5	TBI
Jeep YJ	Wrangler	4.2	Carbureted
Jeep SJ	Grand Wagoneer	5.9	Carbureted
Chrysler	Fifth Avenue or New Port	5.2	Carbureted
Chevrolet	Sprint	1.5	Carbureted
Cadillac	Brougham	5.0	Carbureted
Chevrolet	Caprice Station wagon	5.0	Carbureted
Honda	Prelude	1958 CC	Carbureted
Ford	Festiva	1.3	Carbureted

TABLE C-4

TEST FUEL SPECIFICATIONS

Base Hydrocarbon Fuel	RVP	Distillation Temperatures, °F		
		10%	50%	90%
A	10.5	120	200	340
B	5.5	148	200	340
C	10.5	120	245	340
D	5.5	148	245	340
E	8.0	133	225	340

- Tolerance on RVP shall be $\pm$ 0.5 psi.
- Tolerances on distillation temperatures are $\pm$ 5°F.
- Minimum delta T_{10} and T_{50} values are also specified as follows:
  a) T_{10} for Fuels B and D shall be at least 23°F higher than Fuels A and C.
  b) T_{50} for Fuels C and D shall be at least 40°F higher than Fuels A and B.
- Fuels shall contain no more than 3% Benzene.
- Fuels shall not exceed 437°F endpoint.
- Fuels shall be unleaded and have a minimum (R+M)/2 octane rating of 88.
- Fuels shall not contain more than 40% aromatics.
- Fuels shall contain an antioxidant and a corrosion inhibitor.
- Fuels shall contain less than 0.5% MtBE or EtOH.

TEST FUEL SPECIFICATIONS - (Continued)

Test Fuel Numbers			Finished Blend	Base Fuel
Hydrocarbon	15% MtBE	10% EtOH	RVP, psi	Used For Blend
1	6	11	11.5 $\pm$ 0.3	A
2	7	12	7.0 $^{+0.0}_{-0.5}$	B
3	8	13	11.5 $\pm$ 0.3	C
4	9	14	7.0 $^{+0.0}_{-0.5}$	D
5	10	15	9.0 $\pm$ 0.3	E

- Fuels 1-5 are hydrocarbon-only fuels to be made by adding n-butane (nominally 2%) to Base Fuels A-E, respectively, to achieve specified RVP.
- Fuels 6-10 are 15.0 $\pm$ 0.5% (v) MtBE fuels to be made by adding 18% (v) MtBE to Base Fuels A-E, respectively, and pressurizing with n-butane to achieve the specified RVP.
- Fuels 11-15 are 10.0 $\pm$ 0.5% (v) EtOH fuels made by adding 11% (v) EtOH to Base Fuels A-E, respectively. Pressurizing with n-butane, if necessary, is permissible to achieve RVP specification. EtOH shall be denatured with unleaded gasoline (CDA Formula #20).

ATTACHMENT 1

CRC COLD START AND WARMUP DRIVEABILITY PROCEDURE

TEST PROCEDURE AND DATA RECORDING

A. Record all necessary test information at the top of the data sheet.

B. Start engine per Owner's Manual Procedure. Record start time.

C. If engine fails to start after 15 seconds of cranking, stop cranking. Follow Owner's Manual procedure for this situation. This will be called a no-start. Record NS in the initial start time box on the data sheet.

D. Record idle quality in "Neutral" or "Park" immediately after start; foot should be removed from accelerator pedal.

E. If engine stalls, repeat Steps B and C. Record number of stalls and starting time of required restarts.

Note that space has been provided on the data sheet for only three restarts. In the demerit calculation system, only the first three stalls add to the demerit total. If the engine stalls a fourth time, restart and proceed to the next step as quickly as possible without recording restart time.

F. Allow engine to idle 15 seconds. Apply brakes (right foot), shift to normal drive range, and record idle quality. If engine stalls, restart immediately. Do not record restart time. Record number of stalls. Idle 5 seconds in "Drive".

Again, the maximum number of stalls contributing to demerits is three. If the engine stalls again, restart and proceed to the next maneuver as quickly as possible. It is important to complete the start-up procedure as quickly as possible to prevent undue warm-up before the driving maneuvers and to maintain vehicle spacing on the test track.

---

* Manifold vacuum for light-throttle and detent accelerations are posted in the car.

G. After 5 seconds in "Drive" (Step F), make a light-throttle (Lt. th) acceleration from 0-25 mph at constant throttle opening beginning at the predetermined manifold vacuum.* Cruise at 25 mph. At the 0.2 mile-marker, open throttle to the detent position and accelerate from 25 to 35 at constant throttle in high gear. Decelerate to a stop, and at the 0.3 mile-marker make a WOT acceleration from 0 to 35 mph. Decelerate to 10 mph, and at the 0.4 mile-marker accelerate at light throttle from 10 to 25 mph. Definitions of light throttle, detent, and WOT accelerations are attached.

Decelerations are to be moderate in anticipation of the maneuver to be performed at the next mile marker.

H. During the above maneuvers, observe and record the severity of any of the following malfunctions (see attached definitions):

1. Hesitation
2. Stumble
3. Surge
4. Stall
5. Backfire

It is possible that during an acceleration, more than one stumble or backfire may occur. Record only the most severe rating for each performance deficiency observed. Do not record the numbers of occurrences. Also, in recording subjective ratings (T, M, or H), be sure the entry is legible. At times, M and H recordings cannot be distinguished from each other.

Record maneuvering stalls on the data sheet in the appropriate column: accelerating or decelerating. If the vehicle should stall before completing the maneuver, record the stall and restart the car as quickly as possible. Bring the vehicle up to the intended final speed of the maneuver. Any additional stalls observed will not add to the demerit total for the maneuver, and it is important to maintain the driving schedule as closely as possible.

I. At the 0.5 mile-marker, brake moderately and slowly make a U turn. Park on the right side of the roadway. Idle for 30 seconds in Drive. Record idle quality and number of stalls.

J. Perform Steps G, H, and I three times (1.5 miles). The mile-marker for the beginning of each maneuver is indicated on the data sheet.

K. After completing the above three cycles and the 30-second idle at the 0.5 mile-marker, make a crowd acceleration (constant predetermined vacuum) from 0-45 mph. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 to 25, and at the 0.9 mile-marker make a 25-35 detent position acceleration. Brake moderately, slowly make a U turn, and bring the vehicle to a complete stop at the 0.0 mile-marker. Make a WOT acceleration from 0 to 30 mph. Decelerate to 10 mph, and at the 0.1 mile-marker accelerate at light throttle from 10 to 25 mph. Decelerate moderately and stop the vehicle at the 0.2 mile-marker. Rate and record malfunctions in these maneuvers as in Step H. Idle in Drive for 30 seconds. This ends the driving schedule. Proceed to the end of the test track and return to the staging area via the access road.

L. Appropriate mile-markers for the start of each maneuver are shown on the data sheet. A sketch of the proposed test route is also attached showing mile-marker locations.

DEFINITIONS AND EXPLANATIONS

Test Run

Operation of a car throughout the prescribed sequence of operating conditions and/or maneuvers for a single test fuel.

Maneuver

A specified single vehicle operation or change of operating conditions (such as idle, acceleration, or cruise) that constitutes one segment of the driveability driving schedule.

Cruise

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

Wide Open Throttle (WOT) Acceleration

"Floorboard" acceleration through the gears from prescribed starting speed. Rate at which throttle is depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

Part-Throttle (PT) Acceleration

An acceleration made an any defined throttle position, or consistent change in throttle position, less than WOT. Several PT accelerations are used. They are:

1. Light Throttle (Lt. Th) - All light-throttle accelerations are begun by opening the throttle to an initial manifold vacuum and maintaining constant throttle position throughout the remainder of the acceleration. The vacuum selected is one inch Hg greater than the initial power cut-in vacuum obtained from carburetor flow curves. However, if a 0-25 mph light-throttle maneuver (car warmed-up) cannot be completed in 0.1 mile, vacuum is decreased in steps of one inch Hg until the 0-25 maneuver can be completed in 0.1 mile. The selected vacuum is posted in each car.

2. Crowd - An acceleration made at a constant intake manifold vacuum. To maintain constant vacuum, the throttle-opening must be continually increased with increasing engine speed. Crowd accelerations are performed at the same vacuum prescribed for the light-throttle acceleration.

3. Detent - All detent accelerations are begun by opening the throttle to the downshift position as indicated by transmission shift characteristic curves. Manifold vacuum corresponding to this point at 25 mph is posted in each car. Constant throttle position is maintained to 35 mph in this maneuver.

Malfunctions

1. Stall

   Any occasion during a test when the engine stops with the ignition on. Three types of stall, indicated by location on the data sheet, are:

   a. Stall; idle - Any stall experienced when the vehicle is not in motion, or when a maneuver is not being attempted.

   b. Stall; maneuvering - Any stall which occurs during a prescribed maneuver or attempt to maneuver.

   c. Stall; decelerating - Any stall which occurs while decelerating between maneuvers.

2. Idle Roughness

An evaluation of the idle quality or degree of smoothness while the engine is idling.

3. Backfire

An explosion in the induction or exhaust system.

4. Hesitation

A temporary lack of vehicle response to opening of the throttle.

5. Stumble

A short, sharp reduction in acceleration after the vehicle is in motion.

6. Surge

Cyclic power fluctuations occurring during acceleration or cruise.

Malfunction Severity Ratings

The number of stalls encountered during any maneuver are to be listed in the appropriate data sheet column. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings.

1. Trace (T) - A level of malfunction severity that is just discernible to a test driver but not to most laymen.

2. Moderate (M) - A level of malfunction severity that is probably noticeable to the average laymen.

3. Heavy (H) - A level of malfunction severity that is pronounced and obvious to both test driver and layman.

Enter a T, M, or H in the appropriate data block to indicate both the occurrence of the malfunction and its severity. More than one type of malfunction may be recorded on each line. If no malfunction occur, enter a dash (-) to indicated that the maneuver was performed and operation was satisfactory during the maneuver.

DEMERIT CALCULATION SYSTEM

A numerical value for driveability during the CRC test is obtained by assigning demerits to operating malfunctions as shown on Page 8. Depending upon the type of malfunction, demerits are assigned in various ways. Demerits for poor starting are obtained by subtracting two seconds from the measured starting time. The number of stalls which occur during idle as well as during driving maneuvers are counted separately and assigned demerits as shown on Page 8. The multiplying x factors of 8 and 32 for idle and maneuvering stalls, respectively, account for the fact that stalls are very undesirable, especially during car maneuvers.

Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, are rated subjectively by the driver on a scale of trace, moderate, or heavy. For these malfunctions, a certain number of demerits is assigned to each of the subjective ratings. However, since all malfunctions are not of equal importance, the demerits are multiplied by the weighting factors shown on Page 8 to yield weighted demerits.

Finally, weighted demerits, demerits for stalls, and demerits for poor starting are summed to obtain total weighted demerits (TWD), which are used as an indication of driveability during the test. As driveability deteriorates, TWD increases.

A restriction is applied in the totaling of demerits to insure that a stall results in the highest possible number of demerits within a given maneuver. When more than one malfunction occurs during a maneuver, demerits are counted for only the malfunction which had the largest number of weighted demerits. Another restriction is that for each idle period, no more than 3 idle stalls are counted.

METHOD FOR CALCULATING TOTAL WEIGHTED DEMERITS (TWD)

Demerits for Poor Starting:

Demerits = Starting Time(s) - 2
Demerits for No Start (NS) = 48

Demerits for Stalls:

Demerits = (No. of Idle Stalls) x 8 + (No. of Maneuvering or Decelerating Stalls) x 32

Demerits for Malfunctions Rated Subjectively:

Demerits for Subjective Ratings

Trace	= 1
Moderate	= 2
Heavy	= 4

Weighting Factors for Each Malfunction

Idle Roughness	= 1
Surge	= 4
Backfire, Stumble, Hesitation	= 6

Weighted Demerits = Demerits x Weighting Factor

Calculation:

Total Weighted Demerits = Weighted Demerits + Demerits for stalls + Demerits for Poor Starting

---

NOTE: When more than one malfunction occurs in a driving maneuver, only the malfunction giving the highest weighted demerits is counted.

CRC Driveability Data Sheet

Run no. | Car | Fuel | Rater | Date | Time | Temperatures: Soak | Run

Starting time, sec.: Initial | Restart 1 | Restart 2 | Restart 3

Idle N. Ruf. stalls | Idle Dr. Ruf. stalls

0.0 0-25 Lt. Th.	0.1 25 Cruise	0.2 25-35 Detent	0.3 0-35 WOT	0.4 10 25 Lt. Th.	0.5 Idle
Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Ruf. stalls
0.5	0.6	0.7	0.8	0.9 *	
0.0	0.1	0.2	0.3	0.4 *	0.5

0.5 0-45 Crowd	0.9 25-35 Detent	0.0 0 35 WOT	0.1 10 25 Lt. Th.	0.2 Idle
Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Hes Stm Srg Bkf Ac Dc Stalls	Ruf. stalls
	*			

* = U-Turn

WARM-UP FUEL TANK TEMPERATURE DATA SHEET

Car No. _____ Driver _____

Date _____ Cloudy: Yes____ No ____

Time _____

Temperature _____

Odometer Start _____

Tank Temp. Start _____

		Odometer	Time	Temperature
Take Temperatures	1.	_____	_____	_____
Periodically	2.	_____	_____	_____
On Warm-up	3.	_____	_____	_____
On public	4.	_____	_____	_____
roads	5.	_____	_____	_____
Return to Renegade	6.	_____	_____	_____
Run one complete crowd cycle on track. End of crowd cycle Idle	7.	_____	_____	_____

APPENDIX D

TEST SCHEDULE

TABLE D-1

Fueling Schedule, Test Days 1-15

Day	Red Group Driver 1	Blue Group Driver 2	Yellow Group Driver 3
1	3	7	12
2	15	1	6
3	6	14	2
4	12	4	10
5	1	10	11
6	9	12	4
7	13	3	8
8	8	11	1
9	4	9	14
10	10	13	3
11	11	2	9
12	5	6	15
13	7	15	5
14	2	8	13
15	14	5	7

TABLE D-2

Fueling Schedule, Test Days 16-30

Day	Red Group Driver 4	Blue Group Driver 5	Yellow Group Driver 6
16	1	8	14
17	7	14	5
18	12	1	6
19	4	7	12
20	15	3	8
21	6	11	2
22	11	2	7
23	5	9	15
24	9	12	1
25	14	4	10
26	10	15	4
27	3	10	11
28	8	13	3
29	13	5	9
30	2	6	13

APPENDIX E

INITIAL FINDINGS OF THE 1989 CRC COLD-START AND WARMUP DRIVEABILITY PROGRAM

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SUSTAINING MEMBERS
American Petroleum Institute
Society of Automotive Engineers, Inc.

INITIAL FINDINGS OF THE

1989 CRC COLD-START AND WARM-UP DRIVEABILITY PROGRAM YAKIMA, WASHINGTON

Prepared by the

1989 Volatility Analysis Panel

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JUNE 1990

Initial Findings

1989 CRC Cold-Start and Warm-Up Driveability Program Yakima, Washington

The CRC Volatility Group conducted a cooperative Cold-Start and Warm-Up Driveability program in Yakima, Washington, from October 9 to November 18, 1989. The following is a brief description of the program and key observations.

A. Objective

The objective of this program was to determine the independent effects of front-end and mid-range volatility on cold-start and warming-up driveability of late model vehicles at intermediate ambient temperatures (30°F - 50°F). Front-end volatility was described by Reid vapor pressure (RVP) and mid-range volatility was described by the temperature at which 50 percent of the fuel is evaporated (T_{50}). Volatility ranges investigated were those that may be required of future summertime fuels.

B. Conclusions

- Carbureted and TBI vehicles performed at a similar driveability level and responded to fuel type and volatility in a similar manner. PFI vehicles exhibited substantially better driveability in all cases.
- PFI vehicles showed little or no response to changes in front-end volatility (RVP or T_{10}), but showed some degradation in driveability at high T_{50} levels.
- Carbureted and TBI vehicles responded to both front-end and mid-range (T_{50}) volatility; however, a 40°F change in T_{50} always had more effect on driveability than a 4.5 psi change in RVP.
- Driveability cannot be expressed as a simple linear function of the independently controlled volatility factors across the complete data set. At high volatility levels (high RVP and low T_{50}), there is less response to fuel changes than at low volatility levels.
- Compared with hydrocarbon fuels, RVP-controlled splash blends containing 15 volume percent MTBE gave improved driveability, while corresponding blends containing 10 volume percent ethanol degraded driveability.
- At the same volatility levels, the 15 volume percent MTBE fuels and the hydrocarbon fuels exhibited similar performance, while the 10 volume percent ethanol fuels exhibited degraded performance.

C. Program Outline

Test Vehicles: There were twenty-four 1988-1989 model-year test vehicles used in the program. Twenty vehicles had automatic transmissions; four had manual transmissions. There was an equal number of port-fuel-injected (PFI), throttle-body-injected (TBI), and carbureted vehicles.

Test Temperatures: The test program was targeted for ambient temperatures of 30°F - 50°F, and 85 percent of the runs were conducted within the target temperatures. Actual test temperatures were 30°F - 56°F.

Test Fuel: The experimental design consisted of three separate 2x2 squares with a centerpoint fuel, for a total of five fuels per series for hydrocarbon (HC), 10 volume percent ethanol (EtOH), and 15 volume percent MTBE fuels. The test fuel RVP specifications were 7.0, 9.0, and 11.5 psi for low, centerpoint, and high front-end volatility fuels, respectively, in each series. Five base HC blend stocks were prepared with RVP target levels of 5.5, 8.0,and 10.5 psi, and the T_{50} target levels of 200, 225, and 245°F. The T_{90} was specified as 340°F and was held constant for all fuels. The HC series was pressurized with butane only to obtain the test fuel specified RVP's. The 10 volume percent EtOH series of fuels was formed by adding ethanol to each of the five base fuels. The 15 volume percent MTBE series of fuels was formed by adding MTBE to each of the base fuels. The resulting EtOH and MTBE fuels were then pressurized with butane as necessary to achieve the test fuel RVP specifications. The fuel relationship of the oxygenate squares to the HC square is "splash blending" with RVP compensation.

Program Conduct: The program was conducted in two three-week phases. During each phase, each of three drivers was assigned eight vehicles to evaluate on all fifteen test fuels. Phase II of the program was a replicate of Phase I using different drivers.

Driving Schedule: The driving schedule used was the CRC Cold-Start and Warm-Up Driveability Test Procedure, modified to delete the last two cycles, based upon the results of the 1988 CRC Driveability Program. Total Weighted Demerit (TWD) levels from the 1989 program thus cannot be directly compared with TWD levels from previous programs. The procedure utilized consists of a starting procedure to assess starting time and initial idle roughness and stalls, followed by a repetitive series of short accelerations at defined conditions, constant speed conditions, and idle. Observations are made of hesitation, stumble, surge, backfire, stalls, and idle roughness which are rated as to severity (trace, moderate, or heavy). Demerits are assigned to each malfunction and are weighted and summed to a TWD for each test run. Total driving distance is 2.2 miles, which requires about twelve minutes of operation. Only one test per day is performed on each vehicle. At the end of each test, the vehicle fuel tank is drained, refueled with a new test fuel, warmed up on the new test fuel, and parked overnight for evaluation of the new fuel the following day.

D. Observations

Overall Demerit Levels

There were five fuels of each of three fuel compositions, HC, EtOH, MTBE, evaluated in 24 vehicles. The relationship among these fuels represents "splash blending" with RVP compensation to the same level.

The average total weighted demerits corrected for temperature were:

	Test Runs	Mean TWD
Hydrocarbon	240	54.0
EtOH	240	62.3
MTBE	240	43.6

All paired TWD differences are statistically significant at the 99% level.

Effects of RVP, T_{50}, Fuel Type, and Fuel Delivery Systems

Figure 1 presents TWD as a function of RVP for the carbureted and TBI vehicles (16 vehicles) and PFI vehicles (8 vehicles) for each fuel type. All TWD values shown have been corrected for run temperature (to 40°F). Carbureted and TBI vehicles have been combined because their overall responses and TWD levels were generally similar. TWD levels and responses to volatility were noticeably different for the various fuel types and fuel systems, and are described below.

Figure 1A displays the carbureted and TBI demerits generated on HC fuels. Two curves are shown. The upper curve shows the response of driveability to RVP at high levels of T_{50} (240°F), and the lower curve shows the TWD response at lower T_{50} (200°F) levels. The curves indicate that a 4.5 psi increase in RVP reduces TWD by about 16 demerits at either T_{50} level. The curves also indicate that a 40°F decrease in T_{50} level decreases TWD by about 34 demerits at either RVP level.

Figure 1B presents the PFI data in the same fashion. These curves are qualitatively different from the curves in Figure 1A. The TWD levels are appreciably lower for the PFI vehicles. Also, there is no significant change in TWD due to RVP changes, and the changes in TWD level due to changes in T_{50} are considerably smaller than those shown for carbureted and TBI vehicles.

Figures 1C and 1D show the average data for the 10 volume percent EtOH fuels. The major differences between these curves and those shown for the HC fuels are: (1) the T_{50} levels labeled on the curves are lower (a characteristic of splash blending EtOH fuels), and (2) the TWD levels are higher than the HC fuels.

Figures 1E and 1F show the average data for the MTBE fuels. Relative to the HC fuels, the T_{50} levels are lower, as was the case with the EtOH fuels; however, the TWD levels are lower than the HC fuels in the carbureted and TBI vehicles as would be expected with the increased mid-range volatility (i.e., lower T_{50} levels). There is an important distinction shown. The response of TWD to RVP is considerably different at the lower T_{50} levels than at the higher T_{50} levels. At the lower T_{50} values, there is no improvement in driveability with increasing RVP from 6.5 to 11 psi. At higher T_{50} levels, the response of TWD to RVP is similar to the HC fuel response curves even though it is at a lower overall demerit level. This interaction of front-end and mid-range volatility is statistically significant.

Separate expressions relating TWD to fuel volatility can be made for each combination of fuel delivery system, transmission type, and fuel composition. Such expressions are not very useful for comparing different fuel compositions on a common volatility scale. Such comparisons could be and have been made by plotting results as a function of the ASTM Driveability Index (DI); however, DI is not the best, and is possibly not an unbiased, predictor for the average vehicle on the average fuels used in this program, since it was not internally generated from these data. Therefore, a common expression was generated for all fuels and vehicles for this program to facilitate comparisons between fuels and vehicle types on a common scale which best represents the average performance of the fuels in this program. The following expression relates the "Yakima Volatility Factor 1," YVF 1, to RVP and T_{50}:

$$YVF\ 1 = -2.0\ RVP + 0.54\ T_{50}$$

The YVF 1 is not the "best" parameter for any individual fuel set, but it gives the best fit for the entire data set, and is unbiased for a comparison of fuels.

Figure 2 shows the average corrected TWD values for the 24-vehicle fleet for each fuel composition as a function of YVF 1. Because of the presence of a significant interaction term effect (RVP x T_{50}), particularly in the MTBE fuel, the fit of the non-linear data to the simple two-term expression is inadequate. To demonstrate this, two-straight lines have been fitted to each of the three curves. This is the same effect seen in Figure 1E.

The fit of the HC data is excellent and indicates the general increase in TWD with decreasing volatility (increasing YVF 1). The minor break in the curve as shown is not necessary; a single straight line would fit just as well. The two-slope line is only shown to treat all fuel compositions in the same manner.

The MTBE two-line fit is excellent, and is necessary. The slight increase in TWD with increasing volatility (decreasing YVF 1) at the left side of the figure is probably not important. At higher levels of YVF 1, the MTBE curve is very similar to the HC curve.

The interpretation of the HC and MTBE curves is that at equal volatility levels as expressed by YVF 1, the performance of MTBE and HC fuels is very similar. For convenience to aid the reader, the location of four select RVP-T_{50} combinations which generally encompass the range of volatility investigated are shown on the YVF 1 axis.

The EtOH fuel curve is displaced from both the MTBE and HC curves and demonstrates higher TWD at all volatility levels. There is a good deal of uncertainty in the EtOH curve at the lower values of YVF 1 (less than about 100) where average warming-up performance is relatively good as indicated by lower TWD values. At the higher levels of TWD and YVF 1, however, the fit is good and demonstrates an increase of approximately 10-15 demerits at the same volatility levels as HC or MTBE fuels.

It should be noted that YVF 1 is a composite regression fit for the entire fleet of 24 vehicles. Other equations based on such groups of vehicles, such as PFI or PFI automatic transmission vehicles show a different balance of volatility terms in regression equations than YVF 1.

Many readers are more familiar with volatility expressions that use only distillation points in the regression equations. Therefore, YVF 2 based on T_{10} and T_{50} was developed for the 24-vehicle fleet in similar fashion. The equation is:

$$YVF\ 2 = 0.40\ T_{10} + 0.52\ T_{50}$$

The TWD data for all three fuel types are shown in Figure 3. Since T_{10} and RVP are both measures of front-end volatility and therefore highly correlated, the curves appear the same and the same comments apply.

FIGURE 1

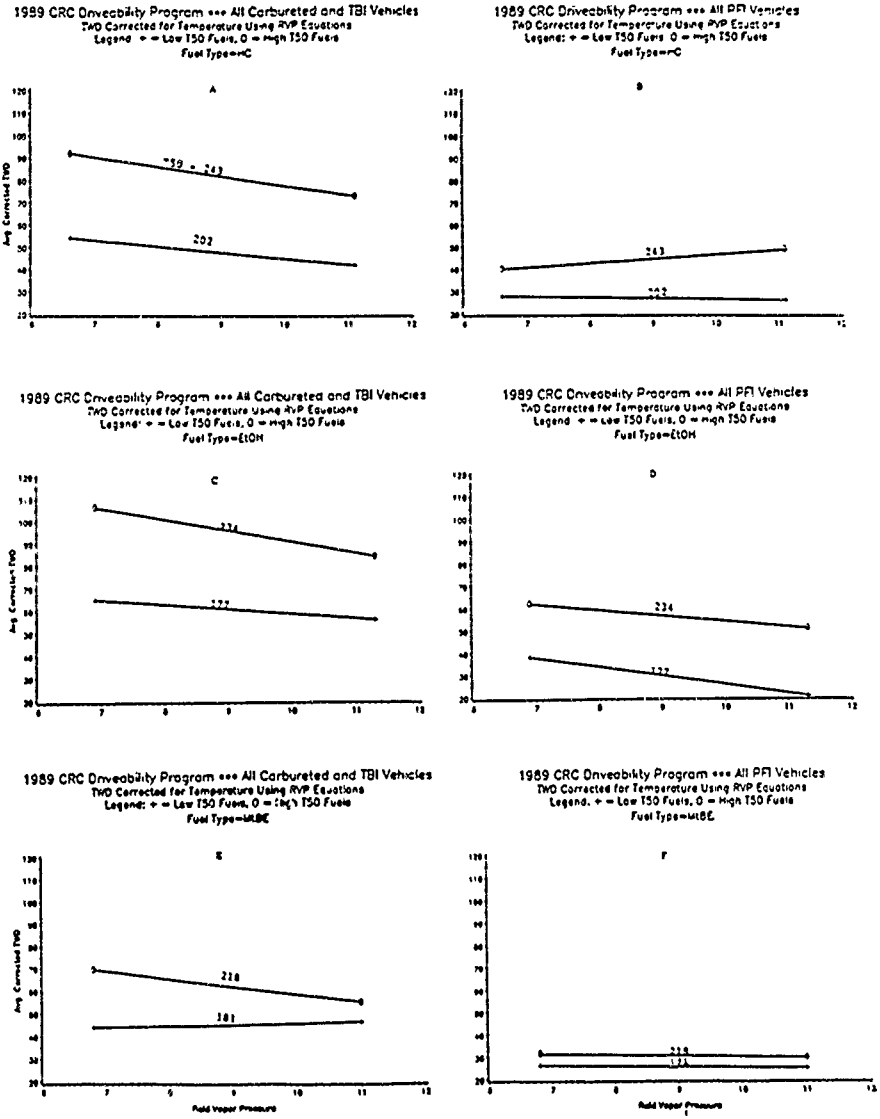

1989 CRC Driveability Program *** All Carbureted and TBI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=nC
A
Avg Corrected TWO
259
243
202
1989 CRC Driveability Program *** All PFI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=nC
B
243
1989 CRC Driveability Program *** All Carbureted and TBI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=EtOH
C
234
1989 CRC Driveability Program *** All PFI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=EtOH
D
234
1989 CRC Driveability Program *** All Carbureted and TBI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=MTBE
E
218
181
Reid Vapor Pressure
1989 CRC Driveability Program *** All PFI Vehicles
TWO Corrected for Temperature Using RVP Equations
Legend: + = Low T50 Fuels, 0 = High T50 Fuels
Fuel Type=MTBE
F
Reid Vapor Pressure

Figure 2
1989 CRC Driveability Program *** All Vehicles
Yakima Volatility Factor 1 = −2.0*RVP + 0.54*T50
Legend: 0 = HC, Δ = MTBE, + = EtOH
All Fuel System Types

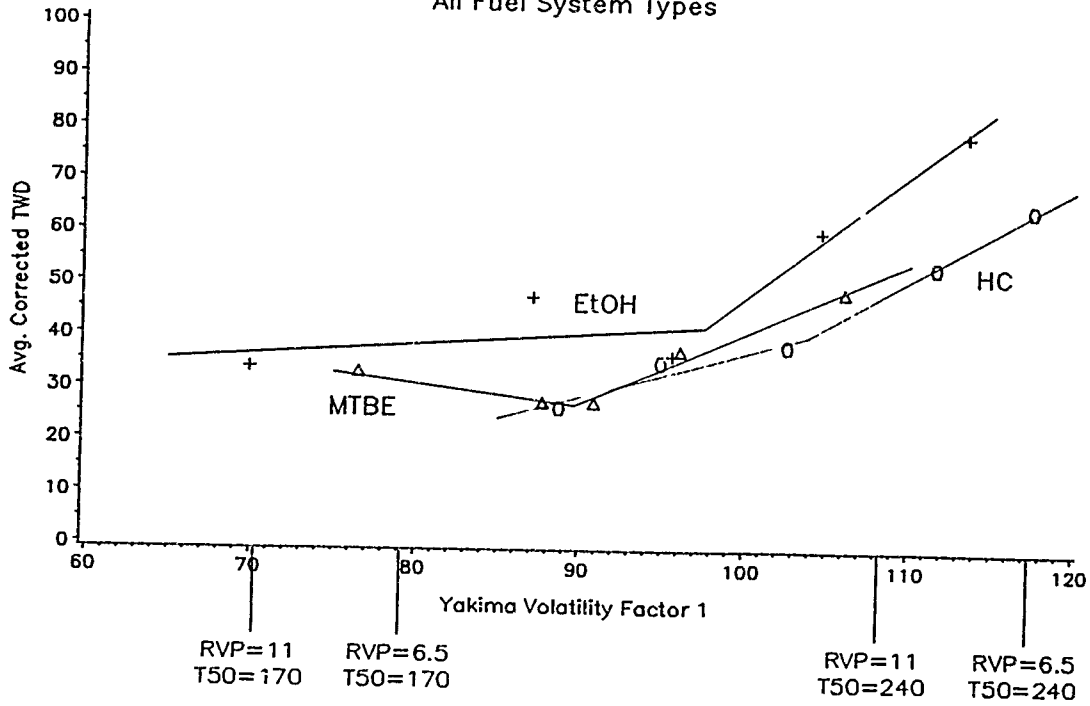
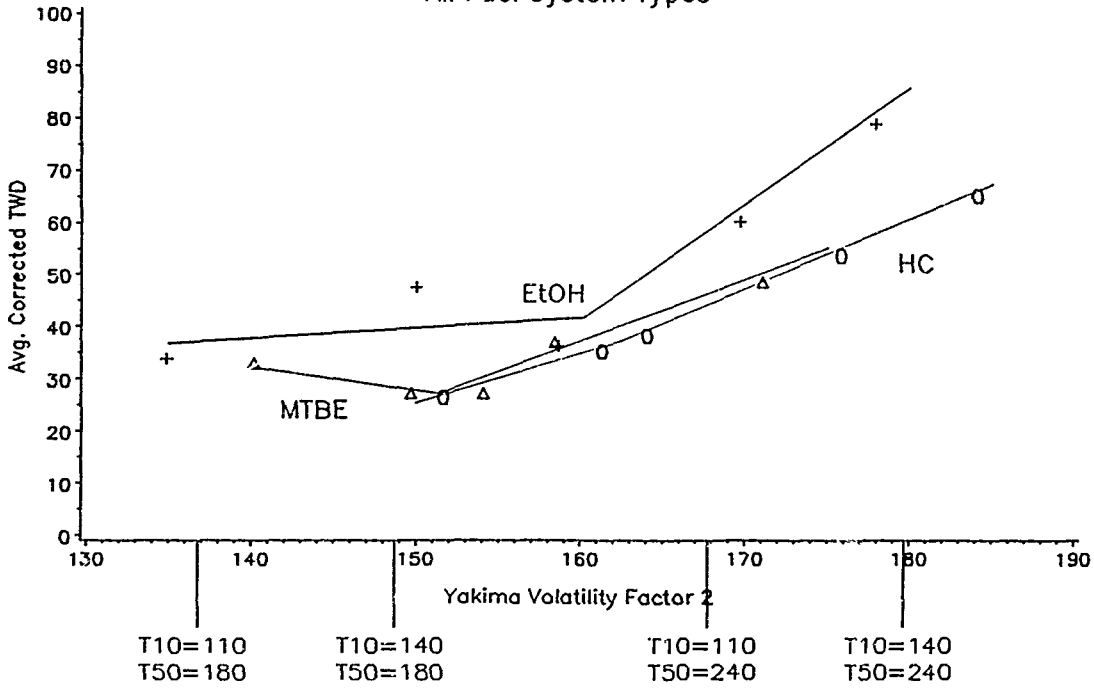


Figure 3
1989 CRC Driveability Program *** All Vehicles
Yakima Volatility Factor 2 = 0.40*T10 + 0.52*T50
Legend: 0 = HC, Δ = MTBE, + = EtOH
All Fuel System Types



APPENDIX F

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

	Fuel 1						Fuel 2					
Lab	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	10.5	11.2	11.2	11.1	10.9	11.2	6.3	6.7	6.4	6.5	6.6	6.8
Distillation, % Evap., °F												
IBP	88	73	87	83	83	86	110	95	104	85	101	109
T_5	106	-	103	101	98	102	137	-	130	132	133	131
T_{10}	116	116	114	114	111	113	147	145	147	144	145	143
T_{20}	136	136	134	134	131	132	160	158	161	158	159	158
T_{30}	159	160	156	157	153	156	174	172	173	171	172	171
T_{40}	182	185	181	181	177	181	187	185	186	184	184	184
T_{50}	204	208	204	204	2[illegible]	204	201	198	199	197	198	198
T_{60}	225	227	224	224	[illegible]	223	217	214	215	213	213	213
T_{70}	247	250	245	245	[illegible]2	245	241	238	236	236	234	234
T_{80}	285	290	280	280	278	262	291	287	277	282	281	280
T_{90}	340	348	332	335	333	324	343	340	335	336	335	333
T_{95}	378	-	368	368	365	359	369	-	360	359	359	354
EP	434	426	418	428	412	404	415	413	406	417	390	413
FIA, %												
Aromatics	22.7	-	-	21.5	21.5	19.0	21.8	-	-	15.0	18.5	17.5
Olefins	15.4	-	-	9.5	9.0	9.3	4.7	-	-	4.0	3.0	6.1
Saturates	61.9	-	-	66.0	69.5	71.7	73.5	-	-	81.0	78.5	76.4

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 3						Fuel 4					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	10.0	11.2	11.2	11.5	11.1	11.5	6.4	6.9	6.7	6.6	6.7	6.8
Distillation, % Evap., °F												
IBP	89	82	87	81	84	91	98	95	90	89	97	108
T_5	109	-	110	97	96	112	133	-	122	122	134	131
T_{10}	125	122	126	113	115	118	151	152	142	141	146	146
T_{20}	161	158	157	146	150	143	181	178	173	169	174	173
T_{30}	201	200	188	189	189	187	206	203	199	194	199	199
T_{40}	229	230	223	224	223	223	227	225	222	216	221	221
T_{50}	249	250	246	245	244	245	245	243	241	235	240	240
T_{60}	268	268	265	263	262	263	264	262	260	253	258	258
T_{70}	287	288	283	283	281	283	283	281	279	274	278	279
T_{80}	307	308	303	303	301	303	305	303	301	296	299	300
T_{90}	337	344	330	332	325	330	353	349	341	335	334	340
T_{95}	373	-	363	361	350	422	400	-	386	378	380	383
EP	425	419	415	422	415	422	444	438	424	430	425	423
FIA, %												
Aromatics	40.7	-	-	37.0	38.0	36.8	38.0	-	-	38.0	36.5	36.6
Olefins	7.7	-	-	6.0	7.0	6.2	16.0	-	-	10.0	13.0	13.3
Saturates	51.6	-	-	57.0	55.0	57.0	46.0	-	-	52.0	50.5	50.1

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INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 5*						Fuel 6					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	-	-	9.0	-	-	9.2	10.1	6.3	11.0	11.2	10.8	11.3
Distillation, % Evap., °F												
IBP	-	-	84	-	-	91	94	71	82	83	87	90
T_5	-	-	96	-	-	106	112	-	103	105	103	104
T_{10}	-	-	119	-	-	121	120	116	113	116	113	113
T_{20}	-	-	143	-	-	142	135	131	129	131	130	128
T_{30}	-	-	169	-	-	168	150	147	145	146	144	144
T_{40}	-	-	197	-	-	194	166	163	161	162	160	160
T_{50}	-	-	221	-	-	219	185	182	179	180	179	179
T_{60}	-	-	237	-	-	237	208	206	201	202	201	201
T_{70}	-	-	258	-	-	257	236	233	228	230	229	229
T_{80}	-	-	289	-	-	287	272	270	264	264	262	262
T_{90}	-	-	335	-	-	332	336	333	324	325	317	324
T_{95}	-	-	368	-	-	361	376	-	361	360	359	357
EP	-	-	421	-	-	429	409	413	413	417	410	411
FIA, %												
Aromatics	-	-	-	-	-	24.9	-	-	-	34.5	21.5	-
Olefins	-	-	-	-	-	8.2	-	-	-	7.0	11.5	-
Saturates	-	-	-	-	-	66.9	-	-	-	58.5	67.0	-

* Due to difficulties in shipping, only Labs 3 and 6 were able to analyze Fuel 5.

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 7						Fuel 8					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	6.5	7.1	6.9	6.9	6.7	6.9	10.2	11.1	11.3	11.4	10.9	11.3
Distillation, % Evap., °F												
IBP	109	96	100	99	100	106	86	87	81	86	83	88
T_5	133	-	126	129	131	127	105	-	90	98	100	102
T_{10}	140	140	137	138	140	137	119	119	107	111	112	112
T_{20}	150	149	147	148	149	148	144	142	132	135	136	134
T_{30}	159	159	157	157	158	157	170	167	157	161	161	159
T_{40}	169	169	167	167	169	168	195	192	185	187	186	185
T_{50}	183	182	180	179	181	181	223	221	214	215	214	214
T_{60}	200	199	197	196	198	198	251	251	244	246	244	244
T_{70}	223	223	219	219	221	221	276	276	270	272	269	270
T_{80}	266	268	260	259	261	262	299	299	294	296	293	294
T_{90}	332	334	323	327	328	328	328	332	321	323	319	321
T_{95}	358	-	351	350	355	351	363	-	350	354	347	350
EP	404	411	407	408	393	406	416	415	409	420	412	411
FIA, %												
Aromatics	-	-	-	33.5	21.5	-	-	-	-	36.5	39.0	-
Olefins	-	-	-	4.5	4.0	-	-	-	-	6.0	5.5	-
Saturates	-	-	-	62.0	74.5	-	-	-	-	52.5	55.5	-

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 9						Fuel 10					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	6.3	7.1	6.8	6.9	6.5	6.7	8.0	8.5	8.7	8.9	8.5	8.9
Distillation, % Evap., °F												
IBP	106	94	93	75	96	102	100	89	92	91	89	93
T_5	136	-	128	126	122	130	123	-	109	115	114	114
T_{10}	147	143	141	140	139	141	132	129	123	127	125	124
T_{20}	165	159	159	159	157	158	146	144	139	143	140	141
T_{30}	180	176	176	175	173	175	162	159	155	158	155	156
T_{40}	200	195	196	194	192	194	182	178	173	176	173	176
T_{50}	226	219	220	218	216	219	205	200	195	198	195	199
T_{60}	252	247	246	246	242	245	229	225	221	223	220	223
T_{70}	274	270	271	269	267	269	252	250	245	247	244	247
T_{80}	298	294	294	293	291	292	286	281	274	279	274	276
T_{90}	340	334	327	329	325	328	340	332	323	328	319	326
T_{95}	388	-	378	372	373	375	386	-	357	364	356	362
EP	430	429	424	422	424	422	411	418	414	419	411	414
FIA, %												
Aromatics	-	-	-	40.5	36.0	-	-	-	-	25.5	26.5	-
Olefins	-	-	-	9.0	13.0	-	-	-	-	6.5	7.5	-
Saturates	-	-	-	50.5	51.0	-	-	-	-	68.0	66.0	-

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 11						Fuel 12					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	10.4	11.5	11.7	11.7	11.2	11.2	6.7	7.0	6.8	6.8	6.7	6.9
Distillation, % Evap., °F												
IBP	96	91	84	88	88	92	118	104	106	105	107	111
T_5	114	-	99	106	107	100	132	-	128	130	128	127
T_{10}	120	118	111	115	116	112	136	134	134	134	133	134
T_{20}	131	130	125	127	129	126	141	139	139	139	139	140
T_{30}	142	141	138	139	140	139	146	144	145	144	143	145
T_{40}	151	150	148	148	149	149	156	151	153	152	148	151
T_{50}	186	176	163	168	165	160	192	186	187	185	179	182
T_{60}	220	220	213	215	214	210	209	206	209	207	203	206
T_{70}	244	242	238	237	237	235	233	226	229	226	222	226
T_{80}	281	280	270	271	273	266	276	269	271	271	263	267
T_{90}	339	340	329	331	328	328	339	334	331	332	327	330
T_{95}	370	-	357	365	366	358	361	-	356	356	352	354
EP	418	416	414	421	413	412	409	410	409	417	393	409
FIA, %												
Aromatics	-	-	-	26.5	20.5	-	-	-	-	17.0	19.5	-
Olefins	-	-	-	8.0	10.0	-	-	-	-	4.0	3.5	-
Saturates	-	-	-	65.5	69.5	-	-	-	-	79.0	77.0	-

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Fuel 13						Fuel 14					
	1	2	3	4	5	6	1	2	3	4	5	6
RVP, psi	10.4	11.5	11.5	11.6	11.2	11.6	6.6	7.2	7.0	6.8	7.0	6.9
Distillation, % Evap., °F												
IBP	92	91	90	87	88	93	112	103	103	103	104	113
T_5	115	-	99	104	109	106	135	-	128	133	133	134
T_{10}	125	123	115	116	121	118	141	141	138	140	140	141
T_{20}	143	141	137	137	140	138	150	150	149	149	149	151
T_{30}	156	155	154	152	154	155	159	159	159	158	156	159
T_{40}	193	182	172	168	172	172	204	202	195	197	195	197
T_{50}	240	239	233	231	233	232	235	236	234	234	233	233
T_{60}	260	259	255	256	255	257	255	256	253	253	253	253
T_{70}	281	281	278	276	278	277	275	277	275	275	275	274
T_{80}	302	302	299	299	298	299	297	300	298	297	296	297
T_{90}	330	335	326	326	326	326	334	346	332	335	334	335
T_{95}	364	-	357	357	357	355	380	-	382	379	383	380
EP	404	416	416	422	412	415	432	434	424	425	423	422
FIA, %												
Aromatics	-	-	-	37.0	42.0	-	-	-	-	40.0	40.0	-
Olefins	-	-	-	6.0	7.0	-	-	-	-	10.0	14.0	-
Saturates	-	-	-	57.0	51.5	-	-	-	-	50.0	46.0	-

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

	Fuel 15					
Lab	1	2	3	4	5	6
RVP, psi	8.6	9.1	9.0	8.2	8.7	8.9
Distillation, % Evap., °F						
IBP	101	92	93	94	98	100
T_5	120	-	115	118	120	119
T_{10}	125	127	124	126	127	126
T_{20}	137	137	135	136	137	138
T_{30}	147	147	146	146	147	148
T_{40}	160	160	157	157	159	159
T_{50}	213	211	203	207	209	206
T_{60}	235	234	232	233	233	233
T_{70}	255	256	246	252	254	251
T_{80}	287	286	279	282	284	281
T_{90}	336	339	324	330	333	330
T_{95}	375	-	-	362	368	363
EP	427	420	342	421	411	417
FIA, %						
Aromatics	-	-	-	25.0	27.0	-
Olefins	-	-	-	8.0	8.0	-
Saturates	-	-	-	67.0	65.0	-

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INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Lab	Base Stock A			Base Stock B			Base Stock C			Base Stock D			Base Stock E		
	4	6	7	4	6	7	4	6	7	4	6	7	4	6	7
RVP, psi	10.1	10.4	10.0	..2	5.6	5.5	10.1	10.2	10.0	5.3	5.7	5.7	7.4	8.1	7.3
Distillation, % Evap., °F															
IBP	97	90	86	70	110	118	90	91	88	102	102	103	73	80	95
T_5	110	105	-	141	142	-	108	108	-	136	124	-	117	115	-
T_{10}	121	116	117	153	150	151	125	123	124	156	144	156	134	128	134
T_{20}	139	134	-	164	162	-	160	156	-	183	172	-	155	151	-
T_{30}	158	158	-	176	174	-	199	197	-	205	198	-	177	174	-
T_{40}	180	183	-	189	186	-	229	228	-	226	221	-	202	198	-
T_{50}	203	205	201	203	200	201	249	248	248	244	240	244	222	220	223
T_{60}	226	225	-	220	215	-	268	266	-	262	259	-	240	237	-
T_{70}	249	246	-	247	238	-	287	285	-	280	279	-	259	256	-
T_{80}	286	283	-	299	284	-	306	304	-	301	300	-	291	286	-
T_{90}	340	337	337	341	337	335	334	332	331	342	339	339	336	337	333
T_{95}	371	366	-	362	357	-	364	364	-	382	381	-	368	358	-
EP	421	416	421	423	415	414	429	422	422	450	423	436	430	421	418
FIA, %															
Aromatics	22.0	20.5	-	23.5	19.3	-	40.0	38.3	-	38.0	35.4	-	27.0	26.8	-
Olefins	10.0	10.3	-	3.0	3.2	-	6.0	6.1	-	13.0	14.8	-	7.0	8.3	-
Saturates	68.0	69.2	-	73.5	77.5	-	54.0	55.6	-	49.0	49.8	-	66.0	64.9	-
API Gravity	63.1	63.9	62.9	56.0	56.8	55.7	54.3	54.7	54.7	53.2	53.8	53.2	59.7	60.0	59.7
Benzene, vol %	1.0	-	-	0.3	-	-	0.7	-	-	1.1	-	-	0.9	-	-
Oxygen, vol %	0	-	-	1.0	-	-	0	-	-	0	-	-	0	-	-
Carbon, %	83.4	-	84.7	85.7	-	85.2	85.9	-	85.3	87.0	-	85.3	84.7	-	84.9
Hydrogen, %	13.5	-	15.3	13.5	-	14.8	12.3	-	14.7	12.6	-	14.7	13.0	-	15.1

APPENDIX G

RAW AND CORRECTED TOTAL WEIGHTED DEMERITS

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
1	1	8	3	10/19/89	40	46	12	23	24	3.464	3.862	3.871
1	1	24	6	11/11/89	50	51	1	22	22	1.000	1.730	1.745
1	2	5	1	10/16/89	35	41	22	22	22	4.690	4.714	4.715
1	2	16	4	11/01/89	30	34	8	8	7	2.828	2.690	2.679
1	3	2	2	10/12/89	50	50	8	9	9	2.828	3.060	3.077
1	3	18	5	11/03/89	33	36	11	11	11	3.317	3.224	3.217
1	4	8	3	10/19/89	40	46	32	32	33	5.657	5.796	5.806
1	4	24	6	11/11/89	50	50	24	25	25	4.899	5.130	5.148
1	5	8	3	10/19/89	40	46	3	3	4	1.732	1.871	1.881
1	5	24	6	11/11/89	50	50	7	8	8	2.646	2.877	2.894
1	6	2	2	10/16/89	40	41	28	28	28	5.292	5.315	5.316
1	6	18	5	11/03/89	33	34	6	6	5	2.449	2.311	2.300
1	7	8	3	10/19/89	40	47	12	12	13	3.464	3.626	3.638
1	7	24	6	11/11/89	50	51	2	3	3	1.414	1.669	1.688
1	8	5	1	10/16/89	35	40	70	70	70	8.367	8.367	8.367
1	8	16	4	11/01/89	30	34	142	131	130	11.916	11.518	11.510
1	9	2	2	10/12/89	50	51	37	50	51	6.083	7.144	7.153
1	9	18	5	11/03/89	33	36	69	64	64	8.307	7.921	7.917
1	10	5	1	10/16/89	35	42	31	33	33	5.568	5.761	5.762
1	10	16	4	11/01/89	30	35	18	12	12	4.243	3.760	3.756
1	11	2	2	10/12/89	50	52	19	34	34	4.359	5.516	5.526
1	11	18	5	11/03/89	33	37	48	44	44	6.928	6.639	6.636
1	12	8	3	10/19/89	40	46	14	21	21	3.742	4.320	4.325
1	12	24	6	11/11/89	50	50	10	22	22	3.162	4.127	4.135
1	13	5	1	10/16/89	35	40	22	22	22	4.690	4.690	4.690
1	13	16	4	11/01/89	30	34	28	21	21	5.292	4.713	4.708
1	14	2	2	10/12/89	50	51	10	23	24	3.162	4.223	4.233
1	14	18	5	11/03/89	33	35	32	26	26	5.657	5.175	5.170
1	15	8	3	10/19/89	40	48	22	32	32	4.690	5.462	5.469
1	15	24	6	11/11/89	50	50	26	38	38	5.099	6.064	6.072
1	16	5	1	10/16/89	35	40	28	28	28	5.292	5.292	5.292
1	16	16	4	11/01/89	30	36	29	24	24	5.385	4.999	4.996
1	17	8	3	10/19/89	40	46	35	38	38	5.916	6.102	6.144
1	17	24	6	11/11/89	50	49	55	59	60	7.416	7.694	7.759
1	18	5	1	10/16/89	35	41	87	88	88	9.327	9.379	9.369
1	18	16	4	11/01/89	30	33	118	109	110	10.863	10.504	10.572
1	19	2	2	10/12/89	50	51	17	22	23	4.123	4.463	4.542
1	19	18	5	11/03/89	33	35	26	24	23	5.099	4.944	4.909
1	20	8	3	10/19/89	40	47	27	30	31	5.196	5.413	5.463
1	20	24	6	11/11/89	50	53	18	23	25	4.243	4.644	4.738
1	21	2	2	10/12/89	50	52	29	34	35	5.385	5.756	5.842
1	21	18	5	11/03/89	33	35	47	45	44	6.856	6.701	6.665
1	22	5	1	10/16/89	35	41	13	13	14	3.606	3.636	3.644
1	22	16	4	11/01/89	30	36	11	9	9	3.317	3.193	3.164
1	23	2	2	10/12/89	50	51	25	30	31	5.000	5.340	5.419
1	23	18	5	11/03/89	33	35	63	61	60	7.937	7.783	7.747
1	24	5	1	10/16/89	35	40	104	104	104	10.198	10.198	10.198
1	24	16	4	11/01/89	30	33	162	153	154	12.728	12.369	12.437
2	1	3	3	10/13/89	48	48	16	31	31	4.000	4.531	4.542
2	1	21	6	11/07/89	45	45	2	11	12	1.414	1.746	1.753

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
2	2	14	1	10/27/89	31	32	24	23	23	4.899	4.714	4.700
2	2	30	4	11/17/89	32	36	13	13	13	3.606	3.513	3.506
2	3	11	2	10/23/89	51	52	12	13	13	3.464	3.742	3.763
2	3	22	5	11/08/89	45	50	6	7	7	2.449	2.681	2.698
2	4	3	3	10/13/89	48	47	28	28	29	5.292	5.453	5.466
2	4	21	6	11/07/89	45	46	0	0	1	0.000	0.139	0.149
2	5	3	3	10/13/89	48	48	10	11	11	3.162	3.347	3.361
2	5	21	6	11/07/89	45	44	5	5	5	2.236	2.329	2.336
2	6	11	2	10/23/89	51	51	9	10	10	3.000	3.254	3.274
2	6	22	5	11/08/89	45	49	10	11	11	3.162	3.370	3.386
2	7	3	3	10/13/89	48	50	26	27	27	5.099	5.330	5.348
2	7	21	6	11/07/89	45	47	0	0	1	0.000	0.162	0.174
2	8	14	1	10/27/89	31	33	154	141	141	12.410	11.945	11.935
2	8	30	4	11/17/89	32	39	113	111	111	10.630	10.564	10.562
2	9	11	2	10/23/89	51	52	38	53	53	6.164	7.322	7.332
2	9	22	5	11/08/89	45	50	50	62	62	7.071	8.036	8.044
2	10	14	1	10/27/89	31	32	49	39	39	7.000	6.228	6.222
2	10	30	4	11/17/89	32	40	43	43	43	6.557	6.557	6.557
2	11	11	2	10/23/89	51	52	37	52	52	6.083	7.240	7.250
2	11	22	5	11/08/89	45	49	36	47	47	6.000	6.868	6.876
2	12	3	3	10/13/89	48	51	2	15	16	1.414	2.475	2.485
2	12	21	6	11/07/89	45	46	19	26	26	4.359	4.938	4.943
2	13	14	1	10/27/89	31	34	47	40	40	6.856	6.277	6.272
2	13	30	4	11/17/89	32	40	38	38	38	6.164	6.164	6.164
2	14	11	2	10/23/89	51	51	30	43	44	5.477	6.538	6.548
2	14	22	5	11/08/89	45	49	18	29	29	4.243	5.111	5.118
2	15	3	3	10/13/89	48	46	44	51	51	6.633	7.212	7.217
2	15	21	6	11/07/89	45	47	14	23	23	3.742	4.417	4.423
2	16	14	1	10/27/89	31	32	79	69	69	8.888	8.117	8.110
2	16	30	4	11/17/89	32	36	78	73	73	8.832	8.446	8.443
2	17	3	3	10/13/89	48	46	56	59	59	7.483	7.669	7.712
2	17	21	6	11/07/89	45	46	54	57	57	7.348	7.534	7.577
2	18	14	1	10/27/89	31	39	97	96	96	9.849	9.798	9.807
2	18	30	4	11/17/89	32	39	77	76	76	8.775	8.724	8.733
2	19	11	2	10/23/89	51	52	66	71	72	8.124	8.495	8.581
2	19	22	5	11/08/89	45	50	46	50	51	6.782	7.091	7.163
2	20	3	3	10/13/89	48	48	34	37	38	5.831	6.078	6.136
2	20	21	6	11/07/89	45	46	20	23	23	4.472	4.658	4.701
2	21	11	2	10/23/89	51	51	42	47	48	6.481	6.821	6.900
2	21	22	5	11/08/89	45	50	53	57	58	7.280	7.589	7.661
2	22	14	1	10/27/89	31	41	10	10	11	3.162	3.193	3.200
2	22	30	4	11/17/89	32	35	32	30	29	5.657	5.502	5.467
2	23	11	2	10/23/89	51	52	58	63	64	7.616	7.987	8.073
2	23	22	5	11/08/89	45	50	36	40	41	6.000	6.309	6.381
2	24	14	1	10/27/89	31	33	210	201	202	14.491	14.132	14.201
2	24	30	4	11/17/89	32	35	122	115	116	11.045	10.789	10.838
3	1	10	3	10/21/89	50	50	24	43	43	4.899	5.563	5.577
3	1	28	6	11/15/89	38	39	1	-1	-1	1.000	0.934	0.932
3	2	1	1	10/11/89	38	40	27	27	27	5.196	5.196	5.196
3	2	27	4	11/14/89	30	37	58	58	58	7.616	7.546	7.541

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
****	*******	***	*****	********	****	****	***	******	******	******	******	******
3	3	7	2	10/18/89	40	44	13	13	13	3.606	3.698	3.705
3	3	20	5	11/06/89	40	46	20	20	21	4.472	4.611	4.621
3	4	10	3	10/21/89	50	48	42	43	43	6.481	6.666	6.680
3	4	28	6	11/15/89	38	37	17	17	17	4.123	4.054	4.048
3	5	10	3	10/21/89	50	48	32	33	33	5.657	5.842	5.856
3	5	28	6	11/15/89	38	38	20	20	20	4.472	4.426	4.422
3	6	7	2	10/18/89	40	45	14	14	14	3.742	3.857	3.866
3	6	20	5	11/06/89	40	46	63	63	64	7.937	8.076	8.086
3	7	10	3	10/21/89	50	49	38	39	39	6.164	6.373	6.388
3	7	28	6	11/15/89	38	37	9	9	9	3.000	2.931	2.925
3	8	1	1	10/11/89	38	40	151	151	151	12.288	12.288	12.288
3	8	27	4	11/14/89	30	37	235	229	229	15.330	15.131	15.126
3	9	7	2	10/18/89	40	41	49	50	50	7.000	7.096	7.097
3	9	20	5	11/06/89	40	48	56	66	66	7.483	8.255	8.262
3	10	1	1	10/11/89	38	40	40	40	40	6.325	6.325	6.325
3	10	27	4	11/14/89	30	31	119	108	108	10.909	10.041	10.033
3	11	7	2	10/18/89	40	42	33	35	35	5.745	5.937	5.939
3	11	20	5	11/06/89	40	47	50	59	59	7.071	7.746	7.752
3	12	10	3	10/21/89	50	50	53	65	65	7.280	8.245	8.253
3	12	28	6	11/15/89	38	37	29	25	25	5.385	5.096	5.093
3	13	1	1	10/11/89	38	41	57	58	58	7.550	7.646	7.647
3	13	27	4	11/14/89	30	31	71	60	60	8.426	7.558	7.550
3	14	7	2	10/18/89	40	40	41	41	41	6.403	6.403	6.403
3	14	20	5	11/06/89	40	43	50	54	54	7.071	7.360	7.363
3	15	10	3	10/21/89	50	48	122	132	132	11.045	11.817	11.824
3	15	28	6	11/15/89	38	39	82	81	81	9.055	8.959	8.958
3	16	1	1	10/11/89	38	45	27	33	33	5.196	5.678	5.683
3	16	27	4	11/14/89	30	33	69	60	60	8.307	7.631	7.626
3	17	10	3	10/21/89	50	49	58	62	63	7.616	7.894	7.958
3	17	28	6	11/15/89	38	39	74	74	73	8.602	8.571	8.564
3	18	1	1	10/11/89	38	43	112	116	115	10.583	10.737	10.708
3	18	27	4	11/14/89	30	32	92	81	83	9.592	9.181	9.260
3	19	7	2	10/18/89	40	40	73	73	73	8.544	8.544	8.544
3	19	20	5	11/06/89	40	44	109	111	111	10.440	10.564	10.593
3	20	10	3	10/21/89	50	48	101	104	105	10.050	10.297	10.354
3	20	28	6	11/15/89	38	37	83	82	81	9.110	9.018	8.996
3	21	7	2	10/18/89	40	42	52	53	53	7.211	7.273	7.287
3	21	20	5	11/06/89	40	48	91	94	95	9.539	9.787	9.844
3	22	1	1	10/11/89	38	45	9	11	12	3.000	3.155	3.190
3	22	27	4	11/14/89	30	32	34	31	30	5.831	5.584	5.526
3	23	7	2	10/18/89	40	40	62	62	62	7.874	7.874	7.874
3	23	20	5	11/06/89	40	46	59	62	62	7.681	7.867	7.910
3	24	1	1	10/11/89	38	40	151	151	151	12.288	12.288	12.288
3	24	27	4	11/14/89	30	32	213	202	204	14.595	14.184	14.262
4	1	6	3	10/17/89	35	40	24	24	24	4.899	4.899	4.899
4	1	26	6	11/13/89	32	37	0	-6	-6	0.000	-0.199	-0.203
4	2	9	1	10/20/89	48	48	18	19	19	4.243	4.428	4.442
4	2	19	4	11/04/89	50	55	34	35	35	5.831	6.178	6.204
4	3	4	2	10/14/89	40	41	6	6	6	2.449	2.473	2.474
4	3	25	5	11/12/89	45	47	16	16	17	4.000	4.162	4.174

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
****	*******	***	*****	********	****	****	***	******	******	******	******	******
4	4	6	3	10/17/89	35	40	28	28	28	5.292	5.292	5.292
4	4	26	6	11/13/89	32	34	28	28	27	5.292	5.153	5.142
4	5	6	3	10/17/89	35	40	30	30	30	5.477	5.477	5.477
4	5	26	6	11/13/89	32	37	21	21	21	4.583	4.513	4.508
4	6	4	2	10/14/89	40	45	23	23	23	4.796	4.911	4.920
4	6	25	5	11/12/89	45	46	66	66	67	8.124	8.263	8.273
4	7	6	3	10/17/89	35	40	30	30	30	5.477	5.477	5.477
4	7	26	6	11/13/89	32	33	49	49	48	7.000	6.838	6.826
4	8	9	1	10/20/89	48	48	80	95	95	8.944	9.475	9.486
4	8	19	4	11/04/89	50	55	148	176	177	12.166	13.161	13.182
4	9	4	2	10/14/89	40	42	54	56	56	7.348	7.541	7.543
4	9	25	5	11/12/89	45	47	49	58	58	7.000	7.675	7.681
4	10	9	1	10/20/89	48	49	130	141	141	11.402	12.270	12.277
4	10	19	4	11/04/89	50	55	89	107	108	9.434	10.881	10.893
4	11	4	2	10/14/89	40	42	62	64	64	7.874	8.067	8.069
4	11	25	5	11/12/89	45	45	96	102	102	9.798	10.280	10.284
4	12	6	3	10/17/89	35	41	79	80	80	8.888	8.985	8.985
4	12	26	6	11/13/89	32	34	48	41	41	6.928	6.349	6.344
4	13	9	1	10/20/89	48	47	69	78	78	8.307	8.982	8.988
4	13	19	4	11/04/89	50	56	57	77	77	7.550	9.093	9.107
4	14	4	2	10/14/89	40	43	53	57	57	7.280	7.569	7.572
4	14	25	5	11/12/89	45	45	79	85	85	8.888	9.370	9.375
4	15	6	3	10/17/89	35	41	168	169	169	12.961	13.058	13.059
4	15	26	6	11/13/89	32	33	87	78	78	9.327	8.652	8.646
4	16	9	1	10/20/89	48	47	46	55	55	6.782	7.458	7.463
4	16	19	4	11/04/89	50	54	32	49	49	5.657	7.007	7.019
4	17	6	3	10/17/89	35	41	114	114	115	10.677	10.708	10.715
4	17	26	6	11/13/89	32	39	87	87	86	9.327	9.296	9.289
4	18	9	1	10/20/89	48	48	132	143	141	11.489	11.899	11.821
4	18	19	4	11/04/89	50	54	182	201	198	13.491	14.209	14.072
4	19	4	2	10/14/89	40	47	103	106	107	10.149	10.365	10.415
4	19	25	5	11/12/89	45	47	98	101	102	9.899	10.116	10.166
4	20	6	3	10/17/89	35	40	69	69	69	8.307	8.307	8.307
4	20	26	6	11/13/89	32	38	45	44	44	6.708	6.646	6.632
4	21	4	2	10/14/89	40	42	85	86	86	9.220	9.281	9.296
4	21	25	5	11/12/89	45	45	81	83	84	9.000	9.155	9.190
4	22	9	1	10/20/89	48	47	56	59	60	7.483	7.700	7.750
4	22	19	4	11/04/89	50	57	36	43	45	6.000	6.525	6.647
4	23	4	2	10/14/89	40	45	61	63	64	7.810	7.965	8.001
4	23	25	5	11/12/89	45	45	85	87	88	9.220	9.374	9.410
4	24	9	1	10/20/89	48	47	159	168	167	12.610	12.968	12.900
4	24	19	4	11/04/89	50	55	167	187	184	12.923	13.692	13.546
4	25	1	1	10/11/89	38	48	24	25	25	4.899	5.084	5.098
4	25	2	3	10/12/89	50	50	41	42	42	6.403	6.634	6.652
4	25	3	2	10/13/89	48	46	32	32	33	5.657	5.796	5.806
4	25	4	1	10/14/89	40	45	22	22	22	4.690	4.806	4.815
4	25	5	3	10/16/89	35	40	20	20	20	4.472	4.472	4.472
4	25	6	2	10/17/89	35	41	44	44	44	6.633	6.656	6.658
4	25	7	1	10/18/89	40	45	8	8	8	2.828	2.944	2.953
4	25	8	3	10/19/89	40	46	25	25	26	5.000	5.139	5.149
4	25	9	2	10/20/89	48	48	49	50	50	7.000	7.185	7.199

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
4	25	10	1	10/21/89	50	50	41	42	42	6.403	6.634	6.652
4	25	11	3	10/23/89	51	52	31	32	32	5.568	5.845	5.866
4	25	12	2	10/24/89	40	40	51	51	51	7.141	7.141	7.141
4	25	13	1	10/25/89	40	45	42	42	42	6.481	6.596	6.605
4	25	14	3	10/27/89	30	32	52	51	51	7.211	7.026	7.012
4	25	15	2	10/28/89	32	42	38	38	38	6.164	6.211	6.214
4	25	16	4	11/01/89	30	33	133	133	132	11.533	11.371	11.358
4	25	17	6	11/02/89	25	30	90	89	89	9.487	9.256	9.238
4	25	18	5	11/03/89	33	35	59	59	59	7.681	7.565	7.557
4	25	19	4	11/04/89	50	56	53	54	54	7.280	7.650	7.678
4	25	20	6	11/06/89	40	46	61	61	62	7.810	7.949	7.959
4	25	21	5	11/07/89	45	44	70	70	70	8.367	8.459	8.466
4	25	22	4	11/08/89	45	47	57	57	58	7.550	7.712	7.724
4	25	23	6	11/09/89	53	55	33	34	34	5.745	6.092	6.118
4	25	24	5	11/11/89	50	51	88	89	89	9.381	9.635	9.654
4	25	25	4	11/12/89	45	45	57	57	57	7.550	7.665	7.674
4	25	26	6	11/13/89	32	35	62	62	62	7.874	7.758	7.750
4	25	27	5	11/14/89	30	31	81	80	80	9.000	8.792	8.776
4	25	28	4	11/15/89	38	37	64	64	64	8.000	7.931	7.925
4	25	29	6	11/16/89	34	35	14	14	14	3.742	3.626	3.617
4	25	30	5	11/17/89	32	38	64	64	64	8.000	7.954	7.950
4	26	1	2	10/11/89	38	45	40	42	43	6.325	6.479	6.515
4	26	2	1	10/12/89	50	51	28	33	34	5.292	5.632	5.710
4	26	3	3	10/13/89	48	49	54	58	59	7.348	7.627	7.691
4	26	4	2	10/14/89	40	48	39	42	43	6.245	6.492	6.550
4	26	5	1	10/16/89	35	40	42	42	42	6.481	6.481	6.481
4	26	6	3	10/17/89	35	42	39	40	40	6.245	6.307	6.321
4	26	7	2	10/18/89	40	40	45	45	45	6.708	6.708	6.708
4	26	8	1	10/19/89	40	46	50	53	53	7.071	7.257	7.299
4	26	9	3	10/20/89	48	49	34	38	39	5.831	6.109	6.174
4	26	10	2	10/21/89	50	48	27	30	31	5.196	5.443	5.501
4	26	11	1	10/23/89	51	52	44	49	50	6.633	7.004	7.090
4	26	12	3	10/24/89	40	37	36	35	34	6.000	5.907	5.836
4	26	13	2	10/25/89	40	44	45	47	47	6.708	6.832	6.860
4	26	14	1	10/27/89	31	34	87	84	84	9.327	9.142	9.099
4	26	15	3	10/28/89	32	42	34	35	35	5.831	5.893	5.907
4	26	16	5	11/01/89	30	33	56	53	52	7.483	7.267	7.217
4	26	17	4	11/02/89	25	30	60	56	55	7.746	7.437	7.365
4	26	18	6	11/03/89	33	37	36	35	34	6.000	5.907	5.886
4	26	19	5	11/04/89	50	57	47	54	56	6.856	7.381	7.503
4	26	20	4	11/06/89	40	46	55	58	58	7.416	7.602	7.645
4	26	21	6	11/07/89	45	44	33	35	35	5.745	5.868	5.897
4	26	22	5	11/08/89	45	49	44	48	49	6.633	6.911	6.976
4	26	23	4	11/09/89	53	55	30	36	38	5.477	5.941	6.048
4	26	24	6	11/11/89	50	49	21	25	26	4.583	4.861	4.925
4	26	25	5	11/12/89	45	45	62	64	65	7.874	8.029	8.064
4	26	26	4	11/13/89	31	34	41	38	38	6.403	6.218	6.175
4	26	27	6	11/14/89	30	33	27	24	23	5.196	4.980	4.930
4	26	28	5	11/15/89	38	39	93	93	92	9.644	9.613	9.606
4	26	29	4	11/16/89	34	35	53	51	50	7.280	7.126	7.090
4	26	30	6	11/17/89	32	39	42	42	41	6.481	6.450	6.443

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
4	27	1	3	10/11/89	38	45	50	56	56	7.071	7.553	7.558
4	27	2	2	10/12/89	50	51	27	40	41	5.196	6.257	6.266
4	27	3	1	10/13/89	48	46	71	78	78	8.426	9.005	9.010
4	27	4	3	10/14/89	40	47	55	64	64	7.416	8.091	8.097
4	27	5	2	10/16/89	40	40	92	92	92	9.592	9.592	9.592
4	27	6	1	10/17/89	35	41	65	66	66	8.062	8.159	8.160
4	27	7	3	10/18/89	40	42	31	33	33	5.568	5.761	5.762
4	27	8	2	10/19/89	40	46	55	62	62	7.416	7.995	8.000
4	27	9	1	10/20/89	48	50	56	68	68	7.483	8.448	8.456
4	27	10	3	10/21/89	50	48	55	65	65	7.416	8.188	8.195
4	27	11	2	10/23/89	51	52	51	66	66	7.141	8.299	8.309
4	27	12	1	10/24/89	40	39	128	127	127	11.314	11.217	11.216
4	27	13	3	10/25/89	40	44	67	72	72	8.185	8.571	8.575
4	27	14	2	10/27/89	30	32	58	48	48	7.616	6.844	6.837
4	27	15	1	10/28/89	32	42	118	120	120	10.863	11.056	11.057
4	27	16	6	11/01/89	30	33	122	113	113	11.045	10.370	10.364
4	27	17	5	11/02/89	25	36	89	84	84	9.434	9.048	9.045
4	27	18	4	11/03/89	33	35	126	120	120	11.225	10.743	10.738
4	27	19	6	11/04/89	50	57	54	75	75	7.348	8.988	9.003
4	27	20	5	11/06/89	40	47	100	109	109	10.000	10.675	10.681
4	27	21	4	11/07/89	45	46	102	109	109	10.100	10.678	10.683
4	27	22	6	11/08/89	45	50	104	116	116	10.198	11.163	11.171
4	27	23	5	11/09/89	53	60	39	63	64	6.245	8.174	8.191
4	27	24	4	11/11/89	50	50	68	80	80	8.246	9.211	9.219
4	27	25	6	11/12/89	45	47	25	34	34	5.000	5.675	5.681
4	27	26	5	11/13/89	31	38	95	93	93	9.747	9.554	9.552
4	27	27	4	11/14/89	30	34	107	100	100	10.344	9.765	9.760
4	27	28	6	11/15/89	38	38	76	74	74	8.718	8.525	8.523
4	27	29	5	11/16/89	34	35	98	92	92	9.899	9.417	9.413
4	27	30	4	11/17/89	32	35	86	80	80	9.274	8.791	8.787
5	1	13	3	10/25/89	40	44	16	24	24	4.000	4.265	4.271
5	1	17	6	11/02/89	25	44	23	31	31	4.796	5.061	5.067
5	2	12	1	10/24/89	40	40	17	17	17	4.123	4.123	4.123
5	2	23	4	11/09/89	53	60	6	7	8	2.449	2.912	2.947
5	3	15	2	10/28/89	32	40	6	6	6	2.449	2.449	2.449
5	3	29	5	11/16/89	34	35	6	6	6	2.449	2.334	2.325
5	4	13	3	10/25/89	40	44	18	18	18	4.243	4.335	4.342
5	4	17	6	11/02/89	25	30	44	43	43	6.633	6.402	6.385
5	5	13	3	10/25/89	40	41	5	5	5	2.236	2.259	2.261
5	5	17	6	11/02/89	25	34	9	9	8	3.000	2.861	2.851
5	6	15	2	10/28/89	32	38	16	16	16	4.000	3.954	3.950
5	6	29	5	11/16/89	34	35	16	16	16	4.000	3.884	3.876
5	7	13	3	10/25/89	40	42	20	20	20	4.472	4.518	4.522
5	7	17	6	11/02/89	25	33	11	11	10	3.317	3.155	3.143
5	8	12	1	10/24/89	40	42	91	95	95	9.539	9.672	9.675
5	8	23	4	11/09/89	53	54	119	145	146	10.909	11.838	11.857
5	9	15	2	10/28/89	32	44	59	64	64	7.681	8.067	8.070
5	9	29	5	11/16/89	34	35	36	30	30	6.000	5.518	5.513
5	10	12	1	10/24/89	40	37	48	44	44	6.928	6.639	6.636
5	10	23	4	11/09/89	53	56	17	37	37	4.123	5.666	5.680

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
5	11	15	2	10/28/89	32	40	58	58	58	7.616	7.616	7.616
5	11	29	5	11/16/89	34	35	57	51	51	7.550	7.068	7.063
5	12	13	3	10/25/89	40	41	23	24	24	4.796	4.892	4.893
5	12	17	6	11/02/89	25	36	60	55	55	7.746	7.360	7.357
5	13	12	1	10/24/89	40	43	10	14	14	3.162	3.452	3.454
5	13	23	4	11/09/89	53	55	33	51	52	5.745	7.191	7.204
5	14	15	2	10/28/89	32	39	36	35	35	6.000	5.904	5.903
5	14	29	5	11/16/89	34	35	31	25	25	5.568	5.085	5.081
5	15	13	3	10/25/89	40	45	42	48	48	6.481	6.963	6.967
5	15	17	6	11/02/89	25	44	76	81	81	8.718	9.104	9.107
5	16	12	1	10/24/89	40	40	33	33	33	5.745	5.745	5.745
5	16	23	4	11/09/89	53	56	29	49	49	5.385	6.929	6.942
5	17	13	3	10/25/89	40	42	37	38	38	6.083	6.145	6.159
5	17	17	6	11/02/89	25	37	172	171	170	13.115	13.022	13.001
5	18	12	1	10/24/89	40	38	120	117	118	10.954	10.852	10.871
5	18	23	4	11/09/89	53	53	109	127	124	10.440	11.107	10.980
5	19	15	2	10/28/89	32	42	51	52	52	7.141	7.203	7.218
5	19	29	5	11/16/89	34	36	67	65	65	8.185	8.062	8.033
5	20	13	3	10/25/89	40	42	36	37	37	6.000	6.062	6.076
5	20	17	6	11/02/89	25	40	84	84	84	9.165	9.165	9.165
5	21	15	2	10/28/89	32	42	38	39	39	6.164	6.226	6.241
5	21	29	5	11/16/89	34	35	40	38	37	6.325	6.170	6.134
5	22	12	1	10/24/89	40	37	30	29	28	5.477	5.384	5.363
5	22	23	4	11/09/89	53	54	15	21	22	3.873	4.306	4.406
5	23	15	2	10/28/89	32	43	40	41	42	6.325	6.417	6.439
5	23	29	5	11/16/89	34	35	45	43	42	6.708	6.554	6.518
5	24	12	1	10/24/89	40	37	148	144	145	12.166	12.012	12.041
5	24	23	4	11/09/89	53	55	116	136	133	10.770	11.540	11.393
6	1	2	3	10/16/89	35	41	29	29	29	5.385	5.429	5.428
6	1	18	6	11/03/89	33	36	1	-1	-1	1.000	0.826	0.828
6	2	3	1	10/13/89	48	48	30	29	29	5.477	5.351	5.360
6	2	21	4	11/07/89	45	46	11	10	10	3.317	3.222	3.228
6	3	12	2	10/24/89	40	39	7	7	7	2.646	2.662	2.660
6	3	30	5	11/17/89	32	39	6	6	6	2.449	2.465	2.464
6	4	2	3	10/12/89	50	51	26	25	25	5.099	4.925	4.937
6	4	18	6	11/03/89	33	34	15	16	16	3.873	3.968	3.961
6	5	2	3	10/12/89	50	50	16	15	15	4.000	3.842	3.853
6	5	18	6	11/03/89	33	35	6	7	7	2.449	2.528	2.523
6	6	12	2	10/24/89	40	38	8	8	8	2.828	2.860	2.858
6	6	30	5	11/17/89	32	40	10	10	10	3.162	3.162	3.162
6	7	2	3	10/12/89	50	51	42	41	41	6.481	6.307	6.319
6	7	18	6	11/03/89	33	35	0	1	1	0.000	0.079	0.074
6	8	3	1	10/13/89	48	51	77	82	82	8.775	9.252	9.247
6	8	21	4	11/07/89	45	47	107	110	110	10.344	10.648	10.644
6	9	12	2	10/24/89	40	37	37	35	35	6.083	5.927	5.921
6	9	30	5	11/17/89	32	35	79	76	76	8.888	8.629	8.619
6	10	3	1	10/13/89	48	50	17	23	23	4.123	4.641	4.662
6	10	21	4	11/07/89	45	44	22	24	24	4.690	4.898	4.906
6	11	12	2	10/24/89	40	37	37	35	35	6.083	5.927	5.921
6	11	30	5	11/17/89	32	39	60	59	59	7.746	7.694	7.692

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
6	12	2	3	10/12/89	50	50	28	34	34	5.292	5.810	5.831
6	12	18	6	11/03/89	33	35	16	13	13	4.000	3.741	3.730
6	13	3	1	10/13/89	48	49	25	30	30	5.000	5.466	5.485
6	13	21	4	11/07/89	45	45	47	50	50	6.856	7.115	7.125
6	14	12	2	10/24/89	40	37	18	16	16	4.243	4.087	4.081
6	14	30	5	11/17/89	32	36	44	42	42	6.633	6.426	6.418
6	15	2	3	10/12/89	50	52	46	53	53	6.782	7.404	7.429
6	15	18	6	11/03/89	33	35	104	101	101	10.198	9.939	9.928
6	16	3	1	10/13/89	48	48	10	15	15	3.162	3.577	3.594
6	16	21	4	11/07/89	45	44	33	35	35	5.745	5.952	5.960
6	17	2	3	10/12/89	50	51	59	54	55	7.681	7.456	7.482
6	17	18	6	11/03/89	33	35	110	112	112	10.488	10.591	10.579
6	18	3	1	10/13/89	48	47	41	51	51	6.403	6.820	6.817
6	18	21	4	11/07/89	45	47	102	112	112	10.100	10.516	10.513
6	19	12	2	10/24/89	40	40	36	36	36	6.000	6.000	6.000
6	19	30	5	11/17/89	32	40	38	38	38	6.164	6.164	6.164
6	20	2	3	10/12/89	50	52	30	25	25	5.477	5.231	5.260
6	20	18	6	11/03/89	33	36	33	35	35	5.745	5.827	5.817
6	21	12	2	10/24/89	40	43	23	22	22	4.796	4.734	4.741
6	21	30	5	11/17/89	32	35	38	40	40	6.164	6.267	6.255
6	22	3	1	10/13/89	48	46	11	8	9	3.317	3.194	3.208
6	22	21	4	11/07/89	45	46	5	2	3	2.236	2.113	2.127
6	23	12	2	10/24/89	40	42	64	63	63	8.000	7.959	7.964
6	23	30	5	11/17/89	32	35	66	68	68	8.124	8.227	8.215
6	24	3	1	10/13/89	48	48	52	64	64	7.211	7.687	7.684
6	24	21	4	11/07/89	45	46	112	121	121	10.583	10.940	10.938
7	1	15	3	10/28/89	32	38	22	21	21	4.690	4.604	4.605
7	1	22	6	11/08/89	45	50	0	5	5	0.000	0.434	0.429
7	2	13	1	10/25/89	40	44	17	17	17	4.123	4.060	4.064
7	2	17	4	11/02/89	25	37	31	31	31	5.568	5.615	5.612
7	3	1	2	10/11/89	38	40	12	12	12	3.464	3.464	3.464
7	3	19	5	11/04/89	50	55	5	3	3	2.236	1.999	2.015
7	4	15	3	10/28/89	32	40	24	24	24	4.899	4.899	4.899
7	4	22	6	11/08/89	45	49	28	27	27	5.292	5.149	5.159
7	5	15	3	10/28/89	32	39	4	4	4	2.000	2.016	2.015
7	5	22	6	11/08/89	45	50	3	2	2	1.732	1.574	1.585
7	6	1	2	10/30/89	30	32	10	11	11	3.162	3.289	3.280
7	6	19	5	11/04/89	50	54	7	5	5	2.646	2.425	2.440
7	7	15	3	10/28/89	32	42	6	6	6	2.449	2.418	2.420
7	7	22	6	11/08/89	45	49	2	1	1	1.414	1.272	1.282
7	8	13	1	10/25/89	40	41	57	57	57	7.550	7.593	7.593
7	8	17	4	11/02/89	25	33	192	189	189	13.856	13.553	13.556
7	9	1	2	10/11/89	38	40	43	43	43	6.557	6.557	6.557
7	9	19	5	11/04/89	50	56	30	39	40	5.477	6.307	6.340
7	10	13	1	10/25/89	40	42	23	24	24	4.796	4.899	4.904
7	10	17	4	11/02/89	25	34	31	28	27	5.568	5.257	5.244
7	11	1	2	10/11/89	38	40	45	45	45	6.708	6.708	6.708
7	11	19	5	11/04/89	50	55	30	39	39	5.477	6.255	6.286
7	12	15	3	10/28/89	32	43	15	17	17	3.873	4.028	4.035
7	12	22	6	11/08/89	45	49	8	13	13	2.828	3.295	3.314

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
7	13	13	1	10/25/89	40	44	24	26	26	4.899	5.106	5.115
7	13	17	4	11/02/89	25	44	46	48	48	6.782	6.990	6.998
7	14	1	2	10/11/89	38	43	24	26	26	4.899	5.054	5.061
7	14	19	5	11/04/89	50	55	28	37	37	5.292	6.069	6.100
7	15	15	3	10/28/89	32	40	58	58	58	7.616	7.616	7.616
7	15	22	6	11/08/89	45	50	3	9	9	1.732	2.250	2.271
7	16	13	1	10/25/89	40	44	37	39	39	6.083	6.290	6.298
7	16	17	4	11/02/89	25	44	43	45	45	6.557	6.765	6.773
7	17	15	3	10/28/89	32	42	40	39	39	6.325	6.284	6.288
7	17	22	6	11/08/89	45	49	64	60	60	8.000	7.815	7.837
7	18	13	1	10/25/89	40	42	73	76	76	8.544	8.663	8.662
7	18	17	4	11/02/89	25	40	101	101	101	10.050	10.050	10.050
7	19	1	2	10/11/89	38	41	34	34	34	5.831	5.810	5.813
7	19	19	5	11/04/89	50	54	59	53	53	7.681	7.394	7.427
7	20	15	3	10/28/89	32	44	36	34	34	6.000	5.918	5.927
7	20	22	6	11/08/89	45	50	9	5	5	3.000	2.795	2.819
7	21	1	2	10/11/89	38	45	16	14	14	4.000	3.897	3.909
7	21	19	5	11/04/89	50	56	34	27	27	5.831	5.503	5.541
7	22	13	1	10/25/89	40	41	27	27	27	5.196	5.176	5.178
7	22	17	4	11/02/89	25	36	6	8	8	2.449	2.531	2.522
7	23	1	2	10/11/89	38	40	46	46	46	6.782	6.782	6.782
7	23	19	5	11/04/89	50	55	75	68	69	8.660	8.353	8.388
7	24	13	1	10/30/89	30	32	182	170	170	13.491	13.015	13.018
7	24	17	4	11/02/89	25	30	131	116	116	11.446	10.850	10.854
8	1	7	3	10/18/89	40	45	8	10	10	2.828	3.045	3.043
8	1	20	6	11/06/89	40	48	1	5	5	1.000	1.347	1.343
8	2	8	1	10/19/89	40	46	22	21	21	4.690	4.596	4.602
8	2	28	4	11/15/89	38	38	31	31	31	5.568	5.599	5.597
8	3	14	2	10/27/89	30	34	8	9	9	2.828	2.923	2.917
8	3	16	5	11/01/89	30	36	5	5	5	2.236	2.299	2.295
8	4	7	3	10/18/89	40	40	31	31	31	5.568	5.568	5.568
8	4	20	6	11/06/89	40	43	35	35	35	5.916	5.869	5.872
8	5	7	3	10/18/89	40	40	14	14	14	3.742	3.742	3.742
8	5	20	6	11/06/89	40	47	14	13	13	3.742	3.631	3.639
8	6	14	2	10/27/89	30	32	9	10	10	3.000	3.126	3.118
8	6	16	5	11/01/89	30	33	30	31	31	5.477	5.588	5.580
8	7	7	3	10/18/89	40	40	15	15	15	3.873	3.873	3.873
8	7	20	6	11/06/89	40	46	9	8	8	3.000	2.905	2.912
8	8	8	1	10/19/89	40	46	63	66	66	7.937	8.198	8.195
8	8	28	4	11/15/89	38	39	167	167	167	12.923	12.879	12.880
8	9	14	2	10/27/89	30	33	62	58	58	7.874	7.511	7.497
8	9	16	5	11/01/89	30	36	23	21	21	4.796	4.589	4.580
8	10	8	1	10/19/89	40	48	28	33	33	5.292	5.706	5.723
8	10	28	4	11/15/89	38	39	66	65	65	8.124	8.072	8.070
8	11	14	2	10/27/89	30	33	69	65	65	8.307	7.944	7.929
8	11	16	5	11/01/89	30	35	29	26	26	5.385	5.126	5.116
8	12	7	3	10/18/89	40	41	22	23	23	4.690	4.742	4.744
8	12	20	6	11/06/89	40	47	10	14	14	3.162	3.525	3.540
8	13	8	1	10/19/89	40	46	29	32	33	5.385	5.696	5.709
8	13	28	4	11/15/89	38	38	69	68	68	8.307	8.203	8.199

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
8	14	14	2	10/27/89	30	34	34	31	30	5.831	5.520	5.507
8	14	16	5	11/01/89	30	34	36	33	32	6.000	5.689	5.677
8	15	7	3	10/18/89	40	42	52	53	53	7.211	7.315	7.319
8	15	20	6	11/06/89	40	46	84	87	88	9.165	9.476	9.489
8	16	8	1	10/19/89	40	47	54	58	58	7.348	7.711	7.726
8	16	28	4	11/15/89	38	37	31	29	29	5.568	5.412	5.406
8	17	7	3	10/18/89	40	42	46	45	45	6.782	6.741	6.746
8	17	20	6	11/06/89	40	44	74	72	72	8.602	8.520	8.530
8	18	8	1	10/19/89	40	46	130	139	139	11.402	11.759	11.757
8	18	28	4	11/15/89	38	37	105	101	101	10.247	10.068	10.070
8	19	14	2	10/27/89	30	32	61	65	64	7.810	7.974	7.955
8	19	16	5	11/01/89	30	34	35	38	37	5.916	6.039	6.025
8	20	7	3	10/18/89	40	40	51	51	51	7.141	7.141	7.141
8	20	20	6	11/06/89	40	48	40	36	37	6.325	6.161	6.180
8	21	14	2	10/27/89	30	41	36	36	36	6.000	5.979	5.982
8	21	16	5	11/01/89	30	33	46	49	49	6.782	6.926	6.909
8	22	8	1	10/19/89	40	47	27	24	24	5.196	5.053	5.069
8	22	28	4	11/15/89	38	37	43	44	44	6.557	6.619	6.612
8	23	14	2	10/27/89	30	39	71	71	71	8.426	8.447	8.444
8	23	16	5	11/01/89	30	34	37	40	39	6.083	6.206	6.192
8	24	8	1	10/19/89	40	46	122	131	131	11.045	11.402	11.400
8	24	28	4	11/15/89	38	39	133	132	132	11.533	11.473	11.473
9	1	11	3	10/23/89	51	52	18	24	24	4.243	4.763	4.757
9	1	29	6	11/16/89	34	36	2	0	0	1.414	1.241	1.243
9	2	6	1	10/17/89	35	40	10	10	10	3.162	3.162	3.162
9	2	24	4	11/11/89	50	53	33	31	32	5.745	5.539	5.553
9	3	9	2	10/20/89	48	47	14	13	13	3.742	3.631	3.639
9	3	23	5	11/09/89	53	54	6	4	4	2.449	2.228	2.244
9	4	11	3	10/23/89	51	52	24	23	23	4.899	4.709	4.722
9	4	29	6	11/16/89	34	35	9	10	10	3.000	3.079	3.074
9	5	11	3	10/23/89	51	52	16	15	15	4.000	3.810	3.823
9	5	29	6	11/16/89	34	35	13	14	14	3.606	3.685	3.679
9	6	9	2	10/20/89	48	49	18	17	17	4.243	4.100	4.110
9	6	23	5	11/09/89	53	53	12	10	11	3.464	3.259	3.273
9	7	11	3	10/23/89	51	52	36	35	35	6.000	5.810	5.823
9	7	29	6	11/16/89	34	35	48	49	49	6.928	7.007	7.002
9	8	6	1	10/17/89	35	40	87	87	87	9.327	9.327	9.327
9	8	24	4	11/11/89	50	50	155	160	160	12.450	12.884	12.879
9	9	9	2	10/20/89	48	47	49	53	53	7.000	7.363	7.377
9	9	23	5	11/09/89	53	56	30	39	40	5.477	6.307	6.340
9	10	6	1	10/17/89	35	40	78	78	78	8.832	8.832	8.832
9	10	24	4	11/11/89	50	51	57	63	64	7.550	8.120	8.143
9	11	9	2	10/20/89	48	48	67	72	72	8.185	8.600	8.617
9	11	23	5	11/09/89	53	55	63	72	72	7.937	8.715	8.746
9	12	11	3	10/23/89	51	51	15	21	22	3.873	4.443	4.466
9	12	29	6	11/16/89	34	35	52	49	49	7.211	6.952	6.942
9	13	6	1	10/17/89	35	41	47	48	48	6.856	6.907	6.910
9	13	24	4	11/11/89	50	50	51	57	57	7.141	7.660	7.681
9	14	9	2	10/20/89	48	48	54	59	59	7.348	7.763	7.780
9	14	23	5	11/09/89	53	55	60	69	69	7.746	8.523	8.555

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
9	15	11	3	10/23/89	51	51	110	116	117	10.488	11.058	11.081
9	15	29	6	11/16/89	34	35	41	38	38	6.403	6.144	6.134
9	16	6	1	10/17/89	35	40	57	57	57	7.550	7.550	7.550
9	16	24	4	11/11/89	50	51	42	48	49	6.481	7.051	7.074
9	17	11	3	10/23/89	51	52	61	56	56	7.810	7.564	7.593
9	17	29	6	11/16/89	34	35	90	92	92	9.487	9.589	9.577
9	18	6	1	10/17/89	35	42	81	84	84	9.000	9.119	9.118
9	18	24	4	11/11/89	50	49	145	158	158	12.042	12.577	12.574
9	19	9	2	10/20/89	48	49	90	86	86	9.487	9.302	9.324
9	19	23	5	11/09/89	53	55	129	122	123	11.358	11.050	11.086
9	20	11	3	10/23/89	51	51	43	38	39	6.557	6.332	6.358
9	20	29	6	11/16/89	34	35	47	49	49	6.856	6.958	6.946
9	21	9	2	10/20/89	48	50	49	45	45	7.000	6.795	6.819
9	21	23	5	11/09/89	53	54	80	74	74	8.944	8.657	8.690
9	22	6	1	10/17/89	35	41	35	35	35	5.916	5.896	5.898
9	22	24	4	11/11/89	50	49	19	15	15	4.359	4.174	4.196
9	23	9	2	10/20/89	48	47	99	96	96	9.950	9.806	9.823
9	23	23	5	11/09/89	53	55	68	61	62	8.246	7.939	7.974
9	24	6	1	10/17/89	35	40	153	153	153	12.369	12.369	12.369
9	24	24	4	11/11/89	50	50	124	139	139	11.136	11.731	11.727
10	1	4	3	10/14/89	40	45	23	25	25	4.796	5.013	5.010
10	1	25	6	11/12/89	45	46	0	3	3	0.000	0.260	0.257
10	2	10	1	10/21/89	50	48	23	22	22	4.796	4.669	4.678
10	2	26	4	11/13/89	31	37	14	14	14	3.742	3.789	3.786
10	3	5	2	10/16/89	40	40	10	10	10	3.162	3.162	3.162
10	3	27	5	11/14/89	30	32	5	6	6	2.236	2.362	2.354
10	4	4	3	10/14/89	40	48	4	3	3	2.000	1.874	1.882
10	4	25	6	11/12/89	45	45	3	2	2	1.732	1.653	1.659
10	5	4	3	10/14/89	40	43	17	17	17	4.123	4.076	4.079
10	5	25	6	11/12/89	45	45	9	8	8	3.000	2.921	2.926
10	6	5	2	10/15/89	40	40	25	25	25	5.000	5.000	5.000
10	6	27	5	11/14/89	30	34	9	10	10	3.000	3.095	3.088
10	7	4	3	10/14/89	40	45	22	21	21	4.690	4.611	4.617
10	7	25	6	11/12/89	45	45	0	-1	-1	0.000	-0.079	-0.074
10	8	10	1	10/21/89	50	48	111	115	115	10.536	10.883	10.879
10	8	26	4	11/13/89	31	38	75	74	74	8.660	8.573	8.574
10	9	5	2	10/16/89	40	40	49	49	49	7.000	7.000	7.000
10	9	27	5	11/14/89	30	37	58	56	56	7.616	7.460	7.454
10	10	10	1	10/21/89	50	48	11	16	16	3.317	3.731	3.748
10	10	26	4	11/13/89	31	33	51	47	47	7.141	6.779	6.764
10	11	5	2	10/16/89	40	40	44	44	44	6.633	6.633	6.633
10	11	27	5	11/14/89	30	36	24	22	22	4.899	4.692	4.683
10	12	4	3	10/14/89	40	42	12	13	13	3.464	3.568	3.572
10	12	25	6	11/12/89	45	45	13	16	16	3.606	3.865	3.875
10	13	10	1	10/21/89	50	49	24	29	29	4.899	5.365	5.384
10	13	26	4	11/13/89	31	35	43	40	40	6.557	6.298	6.288
10	14	5	2	10/16/89	40	40	24	24	24	4.899	4.899	4.899
10	14	27	5	11/14/89	30	32	19	14	14	4.359	3.944	3.928
10	15	4	3	10/14/89	40	42	36	37	37	6.000	6.104	6.108
10	15	25	6	11/12/89	45	45	30	33	33	5.477	5.736	5.747

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt of TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
10	16	10	1	10/21/89	50	48	36	41	41	6.000	6.415	6.431
10	16	26	4	11/13/89	31	35	59	56	56	7.681	7.422	7.412
10	17	4	3	10/14/89	40	42	36	35	35	6.000	5.959	5.964
10	17	25	6	11/12/89	45	47	37	34	34	6.083	5.939	5.956
10	18	10	1	10/21/89	50	49	75	88	88	8.660	9.196	9.193
10	18	26	4	11/13/89	31	38	140	137	137	11.832	11.713	11.714
10	19	5	2	10/16/89	40	40	42	42	42	6.481	6.481	6.481
10	19	27	5	11/14/89	30	31	49	53	53	7.000	7.184	7.163
10	20	4	3	10/14/89	40	41	35	35	35	5.916	5.896	5.898
10	20	25	6	11/12/89	45	47	11	8	8	3.317	3.173	3.190
10	21	5	2	10/16/89	40	42	38	37	37	6.164	6.123	6.128
10	21	27	5	11/14/89	30	33	35	38	38	5.916	6.060	6.043
10	22	10	1	10/21/89	50	48	14	10	11	3.742	3.578	3.597
10	22	26	4	11/13/89	31	34	12	15	14	3.464	3.587	3.573
10	23	5	2	10/16/89	40	40	53	53	53	7.280	7.280	7.280
10	23	27	5	11/14/89	30	33	54	57	57	7.348	7.492	7.475
10	24	10	1	10/21/89	50	50	97	112	112	9.849	10.444	10.440
10	24	26	4	11/13/89	31	33	119	109	109	10.909	10.492	10.495
11	1	5	3	10/15/89	40	40	22	22	22	4.690	4.690	4.690
11	1	27	6	11/14/89	30	36	0	-9	-8	0.000	-0.518	-0.501
11	2	11	1	10/23/89	51	52	9	19	19	3.000	4.217	4.249
11	2	22	4	11/08/89	45	50	17	25	25	4.123	5.137	5.164
11	3	8	2	10/19/89	40	46	16	21	21	4.000	4.608	4.625
11	3	21	5	11/07/89	45	47	18	24	24	4.243	4.952	4.971
11	4	5	3	10/16/89	35	40	8	8	8	2.828	2.828	2.828
11	4	27	6	11/14/89	30	31	30	23	22	5.477	4.565	4.540
11	5	5	3	10/16/89	35	42	4	6	6	2.000	2.203	2.208
11	5	27	6	11/14/89	30	32	4	-3	-3	2.000	1.189	1.167
11	6	8	2	10/19/89	40	47	7	13	13	2.646	3.356	3.374
11	6	21	5	11/07/89	45	46	13	18	18	3.606	4.214	4.230
11	7	5	3	10/16/89	35	40	12	12	12	3.464	3.464	3.464
11	7	27	6	11/14/89	30	31	0	-7	-8	0.000	-0.913	-0.937
11	8	11	1	10/23/89	51	51	47	71	70	6.856	8.280	8.234
11	8	22	4	11/08/89	45	49	65	84	84	8.062	9.228	9.190
11	9	8	2	10/19/89	40	46	31	41	41	5.568	6.133	6.143
11	9	21	5	11/07/89	45	46	47	57	57	6.856	7.421	7.431
11	10	11	1	10/23/89	51	51	17	35	35	4.123	5.160	5.178
11	10	22	4	11/08/89	45	50	16	32	33	4.000	4.942	4.959
11	11	8	2	10/19/89	40	47	39	50	51	6.245	6.905	6.916
11	11	21	5	11/07/89	45	44	42	48	49	6.481	6.858	6.864
11	12	5	3	10/16/89	35	40	10	10	10	3.162	3.162	3.162
11	12	27	6	11/14/89	30	32	8	-5	-5	2.828	2.074	2.061
11	13	11	1	10/23/89	51	52	26	45	46	5.099	6.230	6.250
11	13	22	4	11/08/89	45	49	43	58	58	6.557	7.406	7.421
11	14	8	2	10/19/89	40	48	16	29	29	4.000	4.754	4.767
11	14	21	5	11/07/89	45	46	46	56	56	6.782	7.348	7.358
11	15	5	3	10/16/89	35	40	30	30	30	5.477	5.477	5.477
11	15	27	6	11/14/89	30	33	0	-11	-12	0.000	-0.660	-0.671
11	16	11	1	10/23/89	51	52	29	48	49	5.385	6.516	6.536
11	16	22	4	11/08/89	45	50	34	50	51	5.831	6.773	6.790

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
11	17	5	3	10/16/89	35	40	50	50	50	7.071	7.071	7.071
11	17	27	6	11/14/89	30	37	88	85	84	9.381	9.122	9.119
11	18	11	1	10/23/89	51	52	104	134	132	10.198	11.430	11.352
11	18	22	4	11/08/89	45	49	95	118	116	9.747	10.671	10.612
11	19	8	2	10/19/89	40	46	23	30	30	4.796	5.314	5.320
11	19	21	5	11/07/89	45	46	58	65	65	7.616	8.134	8.140
11	20	5	3	10/16/89	35	40	28	28	28	5.292	5.292	5.292
11	20	27	6	11/14/89	30	34	21	14	14	4.583	4.064	4.058
11	21	8	2	10/19/89	40	46	49	56	56	7.000	7.519	7.525
11	21	21	5	11/07/89	45	45	84	90	90	9.165	9.597	9.602
11	22	11	1	10/23/89	51	52	10	24	24	3.162	4.200	4.212
11	22	22	4	11/08/89	45	50	17	29	29	4.123	4.988	4.998
11	23	8	2	10/19/89	40	46	58	65	65	7.616	8.134	8.140
11	23	21	5	11/07/89	45	47	77	85	85	8.775	9.380	9.387
11	24	11	1	10/23/89	51	51	144	172	170	12.000	13.130	13.057
11	24	22	4	11/08/89	45	50	146	171	170	12.083	13.110	13.044
12	1	1	3	10/30/89	30	32	38	21	21	6.164	5.128	5.162
12	1	19	6	11/04/89	50	56	1	36	35	1.000	3.072	3.005
12	2	4	1	10/14/89	40	42	28	30	30	5.292	5.494	5.500
12	2	18	4	11/03/89	33	35	13	9	9	3.606	3.099	3.085
12	3	6	2	10/17/89	35	40	20	20	20	4.472	4.472	4.472
12	3	24	5	11/11/89	50	49	18	25	26	4.243	5.155	5.180
12	4	1	3	10/11/89	38	41	29	30	30	5.385	5.487	5.489
12	4	19	6	11/04/89	50	55	4	16	17	2.000	3.521	3.561
12	5	1	3	10/11/89	38	40	26	26	26	5.099	5.099	5.099
12	5	19	6	11/04/89	50	55	12	24	25	3.464	4.985	5.026
12	6	6	2	10/17/89	35	40	20	20	20	4.472	4.472	4.472
12	6	24	5	11/11/89	50	49	7	14	15	2.646	3.558	3.583
12	7	1	3	10/11/89	38	40	28	28	28	5.292	5.292	5.292
12	7	19	6	11/04/89	50	54	0	11	12	0.000	1.420	1.457
12	8	4	1	10/14/89	40	43	104	110	110	10.198	10.587	10.574
12	8	18	4	11/03/89	33	34	201	188	188	14.177	13.400	13.426
12	9	6	2	10/17/89	35	41	59	61	61	7.681	7.775	7.777
12	9	24	5	11/11/89	50	50	50	66	67	7.071	8.014	8.030
12	10	4	1	10/14/89	40	45	31	39	39	5.568	6.039	6.047
12	10	18	4	11/03/89	33	37	45	40	40	6.708	6.425	6.420
12	11	6	2	10/17/89	35	41	46	48	48	6.782	6.877	6.878
12	11	24	5	11/11/89	50	50	47	63	64	6.856	7.798	7.815
12	12	1	3	10/11/89	38	40	31	31	31	5.568	5.568	5.568
12	12	19	6	11/04/89	50	55	18	42	43	4.243	5.656	5.681
12	13	4	1	10/14/89	40	47	23	34	35	4.796	5.456	5.467
12	13	18	4	11/03/89	33	36	54	48	47	7.348	6.971	6.965
12	14	6	2	10/17/89	35	40	36	36	36	6.000	6.000	6.000
12	14	24	5	11/11/89	50	51	60	78	78	7.746	8.783	8.801
12	15	1	3	10/11/89	38	45	86	94	94	9.274	9.745	9.753
12	15	19	6	11/04/89	50	55	32	56	57	5.657	7.071	7.096
12	16	4	1	10/14/89	40	42	61	64	64	7.810	7.999	8.002
12	16	18	4	11/03/89	33	36	68	62	61	8.246	7.869	7.863
12	17	1	3	10/11/89	38	43	88	91	92	9.381	9.640	9.643
12	17	19	6	11/04/89	50	55	72	89	90	8.485	9.782	9.797

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
12	18	4	1	10/14/89	40	46	65	85	84	8.062	8.884	8.831
12	18	18	4	11/03/89	33	35	96	83	84	9.798	9.284	9.317
12	19	6	2	10/17/89	35	42	59	61	61	7.681	7.854	7.856
12	19	24	5	11/11/89	50	53	83	98	98	9.110	10.234	10.247
12	20	1	3	10/11/89	38	40	62	62	62	7.874	7.874	7.874
12	20	19	6	11/04/89	50	56	8	27	27	2.828	4.211	4.227
12	21	6	2	10/17/89	35	40	58	58	58	7.616	7.616	7.616
12	21	24	5	11/11/89	50	50	45	57	57	6.708	7.573	7.583
12	22	4	1	10/14/89	40	41	40	41	41	6.325	6.411	6.412
12	22	18	4	11/03/89	33	35	28	22	22	5.292	4.859	4.854
12	23	6	2	10/17/89	35	40	88	88	88	9.381	9.381	9.381
12	23	24	5	11/11/89	50	50	76	88	88	8.718	9.582	9.592
12	24	4	1	10/14/89	40	41	83	86	85	9.110	9.213	9.207
12	24	18	4	11/03/89	33	34	189	174	175	13.748	13.132	13.171
13	1	14	3	10/27/89	30	39	48	46	46	6.928	6.799	6.803
13	1	30	6	11/17/89	32	39	0	-2	-2	0.000	-0.129	-0.125
13	2	7	1	10/18/89	40	40	24	24	24	4.899	4.899	4.899
13	2	29	4	11/16/89	34	35	26	22	22	5.099	4.592	4.579
13	3	10	2	10/21/89	50	48	6	13	13	2.449	3.261	3.282
13	3	28	5	11/15/89	38	37	29	27	26	5.385	5.081	5.073
13	4	14	3	10/27/89	30	33	136	130	130	11.662	10.952	10.933
13	4	30	6	11/17/89	32	35	33	29	29	5.745	5.238	5.224
13	5	14	3	10/27/89	30	34	16	11	11	4.000	3.392	3.375
13	5	30	6	11/17/89	32	38	21	19	19	4.583	4.380	4.374
13	6	10	2	10/21/89	50	49	13	20	21	3.606	4.518	4.542
13	6	28	5	11/15/89	38	38	72	70	70	8.485	8.282	8.277
13	7	14	3	10/27/89	30	32	52	45	45	7.211	6.400	6.378
13	7	30	6	11/17/89	32	35	8	4	4	2.828	2.321	2.308
13	8	7	1	10/18/89	40	40	170	170	170	13.038	13.038	13.038
13	8	29	4	11/16/89	34	35	189	178	179	13.748	13.100	13.121
13	9	10	2	10/21/89	50	50	44	60	61	6.633	7.576	7.592
13	9	28	5	11/15/89	38	38	89	86	86	9.434	9.245	9.242
13	10	7	1	10/18/89	40	40	119	119	119	10.909	10.909	10.909
13	10	29	4	11/16/89	34	36	118	112	111	10.863	10.486	10.479
13	11	10	2	10/21/89	50	48	49	62	62	7.000	7.754	7.767
13	11	28	5	11/15/89	38	39	45	43	43	6.708	6.614	6.612
13	12	14	3	10/27/89	30	42	39	42	42	6.245	6.433	6.437
13	12	30	6	11/17/89	32	40	19	19	19	4.359	4.359	4.359
13	13	7	1	10/18/89	40	44	30	36	37	5.477	5.854	5.861
13	13	29	4	11/16/89	34	35	54	46	46	7.348	6.877	6.869
13	14	10	2	10/21/89	50	48	34	47	47	5.831	6.585	6.598
13	14	28	5	11/15/89	38	37	77	72	72	8.775	8.492	8.487
13	15	14	3	10/27/89	30	34	148	138	138	12.166	11.600	11.590
13	15	30	6	11/17/89	32	35	70	62	62	8.367	7.895	7.887
13	16	7	1	10/18/89	40	40	86	86	86	9.274	9.274	9.274
13	16	29	4	11/16/89	34	35	55	47	47	7.416	6.945	6.937
13	17	14	3	10/27/89	30	41	114	115	115	10.677	10.764	10.765
13	17	30	6	11/17/89	32	40	81	81	81	9.000	9.000	9.000
13	18	7	1	10/18/89	40	42	173	178	178	13.153	13.358	13.345
13	18	29	4	11/16/89	34	35	124	111	112	11.136	10.622	10.655

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
13	19	10	2	10/21/89	50	49	91	101	102	9.539	10.317	10.326
13	19	28	5	11/15/89	38	37	88	85	84	9.381	9.122	9.119
13	20	14	3	10/27/89	30	32	87	78	78	9.327	8.636	8.628
13	20	30	6	11/17/89	32	36	88	83	83	9.381	9.035	9.031
13	21	10	2	10/21/89	50	48	48	57	57	6.928	7.620	7.628
13	21	28	5	11/15/89	38	37	81	78	77	9.000	8.741	8.738
13	22	7	1	10/18/89	40	41	50	51	51	7.071	7.158	7.159
13	22	29	4	11/16/89	34	35	33	27	27	5.745	5.312	5.307
13	23	10	2	10/21/89	50	50	88	100	100	9.381	10.245	10.255
13	23	28	5	11/15/89	38	39	59	58	58	7.681	7.595	7.594
13	24	7	1	10/18/89	40	42	207	212	212	14.387	14.593	14.580
13	24	29	4	11/16/89	34	35	208	195	196	14.422	13.909	13.942
14	1	9	3	10/20/89	48	48	21	38	38	4.583	5.619	5.585
14	1	16	6	11/01/89	30	34	15	2	2	3.873	3.096	3.121
14	2	15	1	10/28/89	32	42	36	38	38	6.000	6.203	6.208
14	2	25	4	11/12/89	45	47	51	57	57	7.141	7.851	7.870
14	3	3	2	10/13/89	48	46	6	11	11	2.449	3.058	3.074
14	3	17	5	11/02/89	25	44	50	53	53	7.071	7.477	7.487
14	4	9	3	10/20/89	48	47	35	41	41	5.916	6.626	6.645
14	4	16	6	11/01/89	30	34	80	75	75	8.944	8.336	8.320
14	5	9	3	10/20/89	48	48	23	30	30	4.796	5.607	5.629
14	5	16	6	11/01/89	30	33	15	9	9	3.873	3.163	3.144
14	6	3	2	10/13/89	48	51	25	34	34	5.000	6.115	6.145
14	6	17	5	11/02/89	25	33	74	68	68	8.602	7.893	7.874
14	7	9	3	10/20/89	48	47	72	78	78	8.485	9.195	9.214
14	7	16	6	11/01/89	30	35	22	18	18	4.690	4.183	4.170
14	8	15	1	10/28/89	32	38	211	207	207	14.526	14.267	14.275
14	8	25	4	11/12/89	45	46	219	232	232	14.799	15.576	15.550
14	9	3	2	10/13/89	48	48	51	64	64	7.141	7.895	7.909
14	9	17	5	11/02/89	25	44	84	90	91	9.165	9.542	9.549
14	10	15	1	10/28/89	32	42	125	128	128	11.180	11.369	11.372
14	10	25	4	11/12/89	45	45	94	102	102	9.695	10.167	10.175
14	11	3	2	10/13/89	48	48	62	75	75	7.874	8.628	8.641
14	11	17	5	11/02/89	25	40	102	102	102	10.100	10.100	10.100
14	12	9	3	10/20/89	48	49	39	54	54	6.245	7.093	7.108
14	12	16	6	11/01/89	30	36	118	112	111	10.863	10.486	10.479
14	13	15	1	10/28/89	32	40	69	69	69	8.307	8.307	8.307
14	13	25	4	11/12/89	45	45	86	94	94	9.274	9.745	9.753
14	14	3	2	10/13/89	48	47	46	57	58	6.782	7.442	7.454
14	14	17	5	11/02/89	25	37	125	120	120	11.180	10.898	10.893
14	15	9	3	10/20/89	48	47	145	156	157	12.042	12.701	12.713
14	15	16	6	11/01/89	30	36	200	194	193	14.142	13.765	13.758
14	16	15	1	10/28/89	32	43	73	78	78	8.544	8.827	8.832
14	16	25	4	11/12/89	45	47	54	65	66	7.348	8.008	8.020
14	17	9	3	10/20/89	48	49	80	90	91	8.944	9.722	9.731
14	17	16	6	11/01/89	30	33	155	147	147	12.450	11.845	11.838
14	18	15	1	10/28/89	32	44	194	204	203	13.928	14.339	14.313
14	18	25	4	11/12/89	45	47	152	170	169	12.329	13.048	13.002
14	19	3	2	10/13/89	48	48	90	99	99	9.487	10.178	10.186
14	19	17	5	11/02/89	25	30	121	109	109	11.000	10.136	10.126

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
14	20	9	3	10/20/89	48	47	72	80	80	8.485	9.090	9.097
14	20	16	6	11/01/89	30	34	90	83	83	9.487	8.968	8.962
14	21	3	2	10/13/89	48	49	61	71	72	7.810	8.588	8.597
14	21	17	5	11/02/89	25	34	90	83	83	9.487	8.968	8.962
14	22	15	1	10/28/89	32	40	95	95	95	9.747	9.747	9.747
14	22	25	4	11/12/89	45	45	49	55	55	7.000	7.432	7.437
14	23	3	2	10/13/89	48	50	74	86	86	8.602	9.467	9.477
14	23	17	5	11/02/89	25	30	97	85	85	9.849	8.984	8.974
14	24	15	1	10/28/89	32	38	215	210	210	14.663	14.457	14.471
14	24	25	4	11/12/89	45	45	161	174	173	12.689	13.202	13.169
15	1	12	3	10/24/89	40	39	14	12	12	3.742	3.612	3.616
15	1	23	6	11/09/89	53	60	0	43	42	0.000	2.590	2.506
15	2	2	1	10/12/89	50	50	15	23	23	3.873	4.887	4.914
15	2	20	4	11/06/89	40	44	25	28	28	5.000	5.406	5.416
15	3	13	2	10/25/89	40	42	12	14	14	3.464	3.567	3.672
15	3	26	5	11/13/89	31	35	6	2	2	2.449	1.942	1.929
15	4	12	3	10/24/89	40	38	20	18	18	4.472	4.269	4.264
15	4	23	6	11/09/89	53	53	0	11	11	0.000	1.318	1.353
15	5	12	3	10/24/89	40	42	11	13	13	3.317	3.519	3.525
15	5	23	6	11/09/89	53	56	4	17	18	2.000	3.622	3.666
15	6	13	2	10/25/89	40	44	11	14	14	3.317	3.722	3.733
15	6	26	5	11/13/89	31	37	18	16	15	4.243	3.938	3.930
15	7	12	3	10/24/89	40	43	6	8	9	2.449	2.754	2.762
15	7	23	6	11/09/89	53	54	0	11	12	0.000	1.420	1.457
15	8	2	1	10/12/89	50	50	84	106	105	9.165	10.460	10.418
15	8	20	4	11/06/89	40	43	174	180	180	13.191	13.579	13.567
15	9	13	2	10/25/89	40	44	44	50	51	6.633	7.010	7.017
15	9	26	5	11/13/89	31	39	30	28	28	5.477	5.383	5.381
15	10	2	1	10/12/89	50	52	15	34	35	3.873	5.004	5.024
15	10	20	4	11/06/89	40	48	42	55	55	6.481	7.235	7.248
15	11	13	2	10/25/89	40	41	40	42	42	6.325	6.419	6.420
15	11	26	5	11/13/89	31	37	39	34	34	6.245	5.962	5.957
15	12	12	3	10/24/89	40	37	19	14	14	4.359	4.076	4.071
15	12	23	6	11/09/89	53	54	9	32	32	3.000	4.319	4.343
15	13	2	1	10/12/89	50	51	5	23	23	2.236	3.273	3.291
15	13	20	4	11/06/89	40	47	58	69	70	7.616	8.276	8.287
15	14	13	2	10/25/89	40	45	24	32	32	4.899	5.370	5.379
15	14	26	5	11/13/89	31	34	50	40	40	7.071	6.506	6.496
15	15	12	3	10/24/89	40	40	112	112	112	10.583	10.583	10.583
15	15	23	6	11/09/89	53	55	8	32	33	2.828	4.242	4.267
15	16	2	1	10/12/89	50	53	16	37	37	4.000	5.225	5.247
15	16	20	4	11/06/89	40	46	46	56	56	6.782	7.348	7.358
15	17	12	3	10/24/89	40	40	58	58	58	7.616	7.616	7.616
15	17	23	6	11/09/89	53	55	60	77	78	7.746	9.043	9.058
15	18	2	1	10/12/89	50	51	53	81	79	7.280	8.410	8.338
15	18	20	4	11/06/89	40	47	106	124	123	10.296	11.015	10.969
15	19	13	2	10/25/89	40	41	36	37	37	6.000	6.086	6.087
15	19	26	5	11/13/89	31	33	54	46	46	7.348	6.743	6.736
15	20	12	3	10/24/89	40	37	62	59	58	7.874	7.615	7.612
15	20	23	6	11/09/89	53	55	12	29	30	3.464	4.761	4.776

Raw and Adjusted TWD

Fuel	Vehicle	Run	Rater	Date	Soak Temp	Run Temp	Raw TWD	Corrected TWD Using RVP Eq	Corrected TWD Using T10 Eq	Raw Sqrt TWD	Corrected Square Root of TWD Using RVP Eq	Corrected Square Root of TWD Using T10 Eq
****	*******	***	*****	********	****	****	***	******	******	******	******	******
15	21	13	2	10/25/89	40	42	34	36	36	5.831	6.004	6.006
15	21	26	5	11/13/89	31	34	71	64	64	8.426	7.908	7.902
15	22	2	1	10/12/89	50	52	2	16	16	1.414	2.451	2.463
15	22	20	4	11/06/89	40	48	18	27	27	4.243	4.934	4.942
15	23	13	2	10/25/89	40	42	84	86	86	9.165	9.338	9.340
15	23	26	5	11/13/89	31	33	58	50	50	7.616	7.011	7.004
15	24	2	1	10/12/89	50	51	89	117	115	9.434	10.564	10.491
15	24	20	4	11/06/89	40	46	143	158	157	11.958	12.574	12.535

Listing of Average Run Temperatures

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicles
1	43.8	42.8	43.6	42.7	44.3	36.8	42.4	43.5	39.8	42.9
2	46.0	41.3	44.8	44.2	47.3	36.5	44.6	45.6	38.9	44.5
3	42.9	41.5	42.6	41.0	42.5	36.8	41.1	42.0	39.1	41.5
4	42.2	45.0	42.9	45.1	44.4	51.0	46.1	44.0	48.0	44.7
5	39.3	46.0	41.0	42.6	40.4	45.8	41.8	40.9	45.9	41.8
6	42.2	43.8	42.6	42.1	41.8	47.0	43.1	42.0	45.4	42.6
7	44.3	40.5	43.3	45.2	46.1	36.0	43.6	45.2	38.3	44.0
8	39.6	44.5	40.8	39.8	39.3	42.0	39.9	39.5	43.3	40.2
9	46.4	44.5	45.9	47.1	47.8	45.3	47.1	47.1	44.9	46.7
10	41.8	44.3	42.4	40.4	39.8	42.5	40.5	40.7	43.4	41.1
11	42.0	44.0	42.5	45.4	44.1	50.5	45.7	44.0	47.3	44.5
12	45.0	41.3	44.1	44.4	45.4	39.5	43.9	44.9	40.4	44.1
13	37.8	38.3	37.9	40.1	40.4	38.5	39.9	39.5	38.4	39.3
14	42.3	41.5	42.1	43.4	40.8	43.5	41.4	42.3	42.5	42.3
15	44.8	48.0	45.6	45.2	42.7	48.8	44.2	44.3	48.4	45.0

Listing of Average Uncorrected TWD

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicles
1	13.6	56.3	24.3	27.7	30.5	117.8	52.3	24.3	87.0	34.8
2	11.9	71.3	26.8	38.9	42.3	126.5	63.3	31.8	98.9	43.0
3	29.4	102.8	47.8	59.3	67.1	142.0	85.8	52.6	122.4	64.3
4	29.1	63.0	37.6	74.9	76.7	160.0	97.5	61.7	111.5	70.0
5	14.5	62.3	26.4	40.5	54.6	123.3	71.8	36.9	92.8	46.2
6	14.8	53.5	24.4	38.9	42.8	76.8	51.3	32.8	65.1	38.2
7	12.4	67.8	26.3	30.5	37.2	121.8	58.3	27.1	94.8	38.4
8	18.6	59.8	28.9	43.6	47.3	122.5	66.1	37.2	91.1	46.2
9	19.9	65.5	31.3	54.6	67.5	125.8	82.1	48.0	95.6	56.0
10	11.8	52.3	21.9	33.3	34.7	107.8	52.9	27.3	80.0	36.0
11	11.5	33.5	17.0	27.1	46.9	122.3	65.8	28.4	77.9	36.6
12	17.1	86.0	34.3	46.7	58.9	108.3	71.3	41.5	97.1	50.8
13	36.3	101.8	52.7	67.3	75.7	178.0	101.3	60.5	139.9	73.7
14	40.8	116.5	59.7	92.1	89.5	180.5	112.3	75.9	148.5	88.0
15	10.7	68.0	25.0	34.8	45.8	97.8	58.8	30.8	82.9	39.5

Listing of Average Uncorrected Square Root of TWD

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicle
1	3.435	6.187	4.123	5.104	5.341	10.779	6.701	4.674	8.483	5.309
2	3.031	7.113	4.051	5.968	6.353	11.040	7.525	5.202	9.077	5.848
3	5.205	8.379	5.999	7.516	7.958	11.764	8.910	6.955	10.072	7.475
4	5.214	6.502	5.536	8.464	8.650	12.628	9.645	7.545	9.565	7.881
5	3.614	7.311	4.538	6.203	7.047	11.082	8.056	5.679	9.197	6.266
6	3.482	6.376	4.205	5.970	6.183	8.574	6.781	5.287	7.475	5.652
7	3.249	6.524	4.068	5.321	5.813	10.883	7.080	4.847	8.703	5.490
8	4.137	6.172	4.645	6.403	6.802	11.057	7.865	5.843	8.614	6.305
9	4.270	6.858	4.917	7.255	7.997	11.137	8.782	6.582	8.998	6.985
10	3.123	5.998	3.842	5.597	5.726	10.312	6.873	4.893	8.155	5.437
11	3.116	4.902	3.562	4.900	5.548	11.007	7.663	4.859	7.954	5.375
12	3.831	7.885	4.844	6.710	7.450	10.179	8.132	6.068	9.032	6.562
13	5.496	8.428	6.229	7.925	8.593	13.274	9.763	7.397	10.851	7.972
14	6.081	9.445	6.922	9.368	9.362	13.402	10.372	8.380	11.424	8.887
15	2.882	6.524	3.793	5.525	6.395	9.742	7.232	4.993	8.133	5.517

Listing of Average TWD Corrected Using RVP Equation

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicles
1	13.9	61.5	25.8	30.9	32.3	113.5	52.6	26.2	87.5	36.4
2	12.3	73.5	27.6	43.9	45.3	122.0	64.5	34.9	97.8	45.4
3	29.7	105.5	48.6	60.4	68.3	137.5	85.6	53.5	121.5	64.9
4	29.3	72.3	40.0	81.1	78.5	174.8	102.6	64.8	123.5	74.5
5	14.5	73.8	29.3	43.7	54.8	131.0	73.9	38.3	102.4	49.0
6	14.6	55.0	24.7	40.1	41.9	87.0	53.2	33.0	71.0	39.3
7	11.9	68.0	25.9	33.5	34.6	115.8	54.9	27.3	91.9	38.1
8	18.6	62.0	29.4	43.5	47.6	125.8	67.1	37.3	93.9	46.7
9	19.3	67.8	31.4	58.7	64.1	133.5	81.4	48.5	100.6	57.2
10	11.4	54.3	22.1	33.6	34.8	111.5	53.9	27.3	82.9	36.5
11	13.3	42.0	20.4	35.8	51.8	148.8	76.0	33.8	95.4	44.1
12	21.1	88.8	38.0	53.9	65.2	107.0	75.6	47.4	97.9	55.8
13	34.5	98.0	50.4	67.3	76.2	174.0	100.6	60.1	136.0	72.8
14	42.7	119.8	61.9	97.5	90.3	189.5	115.1	78.9	154.6	91.5
15	14.6	85.3	32.3	43.1	48.8	120.0	66.6	36.3	102.6	47.3

Listing of Average TWD Corrected Using T10 Equation

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicles
1	14.0	61.5	25.9	31.0	32.8	114.0	53.1	26.4	87.8	36.6
2	12.6	73.8	27.9	44.1	45.9	122.5	65.1	35.2	98.1	45.7
3	29.8	105.5	48.8	60.4	68.3	138.3	85.8	53.6	121.9	65.0
4	29.3	72.5	40.1	81.1	79.2	172.5	102.5	65.0	122.5	74.6
5	14.4	74.0	29.3	43.8	54.7	130.0	73.5	38.2	102.0	48.9
6	14.6	55.0	24.7	40.1	42.2	87.0	53.4	33.0	71.0	39.4
7	11.9	68.0	25.9	33.5	34.7	115.8	54.9	27.4	91.9	38.1
8	18.6	62.0	29.4	43.5	47.4	125.8	67.0	37.2	93.9	46.6
9	19.4	67.8	31.5	59.0	64.3	133.5	81.6	48.7	100.6	57.4
10	11.4	54.3	22.1	33.6	34.8	111.5	53.9	27.3	82.9	36.5
11	13.1	42.0	20.3	36.1	51.7	147.0	75.5	33.9	94.5	44.0
12	21.5	88.5	38.3	54.1	65.3	107.0	75.8	47.7	97.8	56.0
13	34.5	98.3	50.4	67.4	76.1	174.5	100.7	60.1	136.4	72.8
14	42.7	119.8	61.9	97.6	90.4	188.8	115.0	79.0	154.3	91.5
15	14.8	84.8	32.3	43.4	48.8	118.5	66.3	36.4	101.6	47.3

Listing of Average Square Root of TWD Corrected Using RVP Equation

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicle
1	3.524	6.369	4.235	5.363	5.472	10.612	6.757	4.844	8.491	5.452
2	3.169	7.196	4.176	6.372	6.577	10.861	7.648	5.473	9.029	6.065
3	5.273	8.479	6.074	7.612	8.036	11.597	8.926	7.037	10.038	7.538
4	5.264	6.834	5.656	8.952	8.786	13.192	9.888	7.796	10.013	8.165
5	3.599	7.709	4.626	6.450	7.060	11.378	8.139	5.778	9.543	6.405
6	3.448	6.539	4.220	6.077	6.147	8.991	6.858	5.309	7.765	5.718
7	3.182	6.546	4.023	5.590	5.688	10.644	6.927	4.897	8.595	5.513
8	4.143	6.367	4.699	6.390	6.817	11.175	7.907	5.844	8.771	6.332
9	4.168	7.054	4.890	7.624	7.838	11.449	8.741	6.652	9.251	7.085
10	3.094	6.182	3.866	5.619	5.729	10.461	6.912	4.895	8.322	5.466
11	3.318	5.420	3.844	5.406	6.901	12.085	8.197	5.228	8.753	5.816
12	4.338	8.047	5.265	7.128	7.918	10.128	8.471	6.528	9.087	6.955
13	5.276	8.202	6.008	7.931	8.629	13.120	9.752	7.344	10.661	7.897
14	6.309	9.639	7.142	9.686	9.427	13.761	10.511	8.595	11.700	9.113
15	3.372	7.560	4.419	6.014	6.626	10.641	7.630	5.405	9.100	6.021

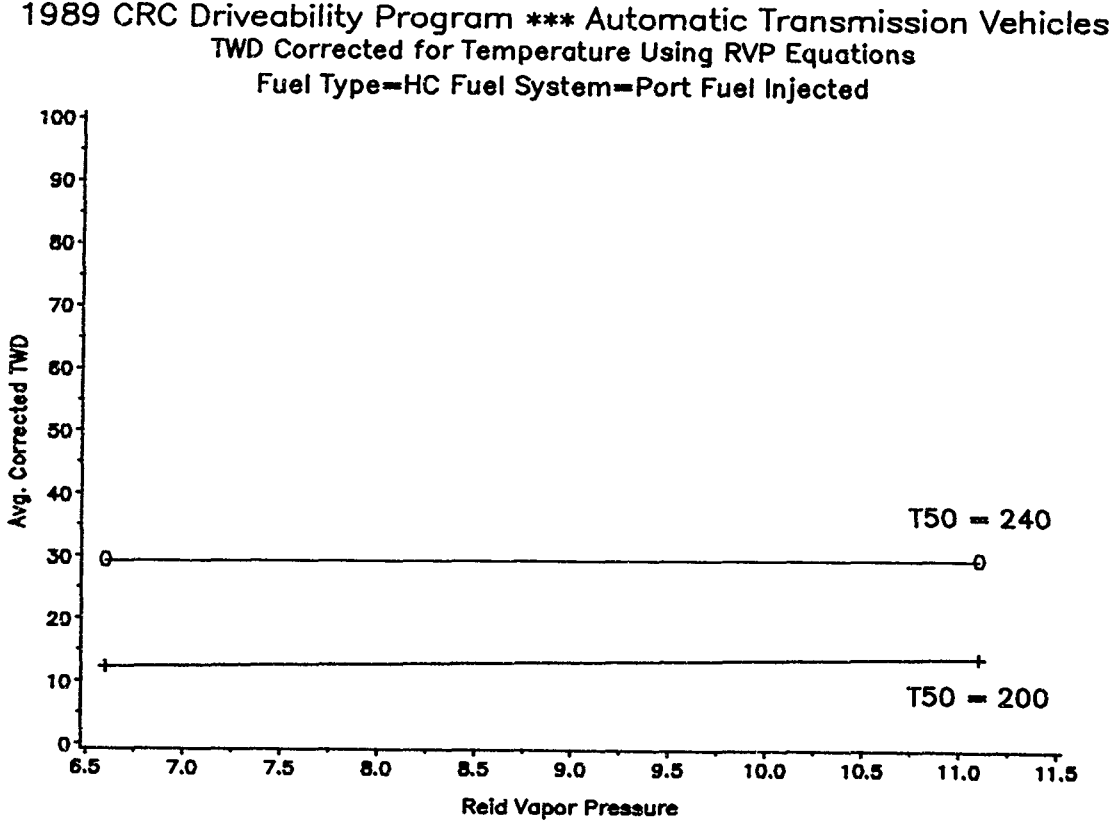
Listing of Average Square Root of TWD Corrected Using T10 Equation

Fuel	PFI Auto	PFI Manual	All PFI	TBI Auto	Carb Auto	Carb Manual	All Carb	All Auto	All Manual	All Vehicle
1	3.530	6.373	4.241	5.365	5.503	10.644	6.788	4.856	8.509	5.465
2	3.180	7.198	4.185	6.375	6.629	10.895	7.696	5.493	9.046	6.085
3	5.278	8.481	6.079	7.613	8.053	11.629	8.947	7.045	10.055	7.546
4	5.267	6.841	5.661	8.957	8.818	13.085	9.885	7.808	9.963	8.167
5	3.598	7.717	4.628	6.452	7.063	11.321	8.127	5.779	9.519	6.402
6	3.450	6.537	4.222	6.081	6.151	8.988	6.860	5.313	7.762	5.721
7	3.186	6.546	4.026	5.601	5.703	10.646	6.938	4.907	8.596	5.522
8	4.143	6.365	4.698	6.389	6.815	11.175	7.905	5.843	8.770	6.331
9	4.175	7.051	4.894	7.639	7.857	11.447	8.754	6.665	9.249	7.096
10	3.096	6.180	3.867	5.620	5.729	10.460	6.912	4.896	8.320	5.467
11	3.324	5.403	3.843	5.415	6.905	12.016	8.183	5.235	8.710	5.814
12	4.351	8.042	5.274	7.135	7.923	10.131	8.475	6.537	9.087	6.962
13	5.270	8.209	6.005	7.931	8.629	13.130	9.754	7.342	10.670	7.897
14	6.315	9.633	7.144	9.691	9.428	13.739	10.506	8.599	11.686	9.114
15	3.385	7.527	4.420	6.023	6.628	10.583	7.617	5.413	9.055	6.020

APPENDIX H

DISPLAY OF RESPONSE
OF DRIVEABILITY TO FUEL VOLATILITY

FIGURE H-1


1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Port Fuel Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 240
T50 = 200
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

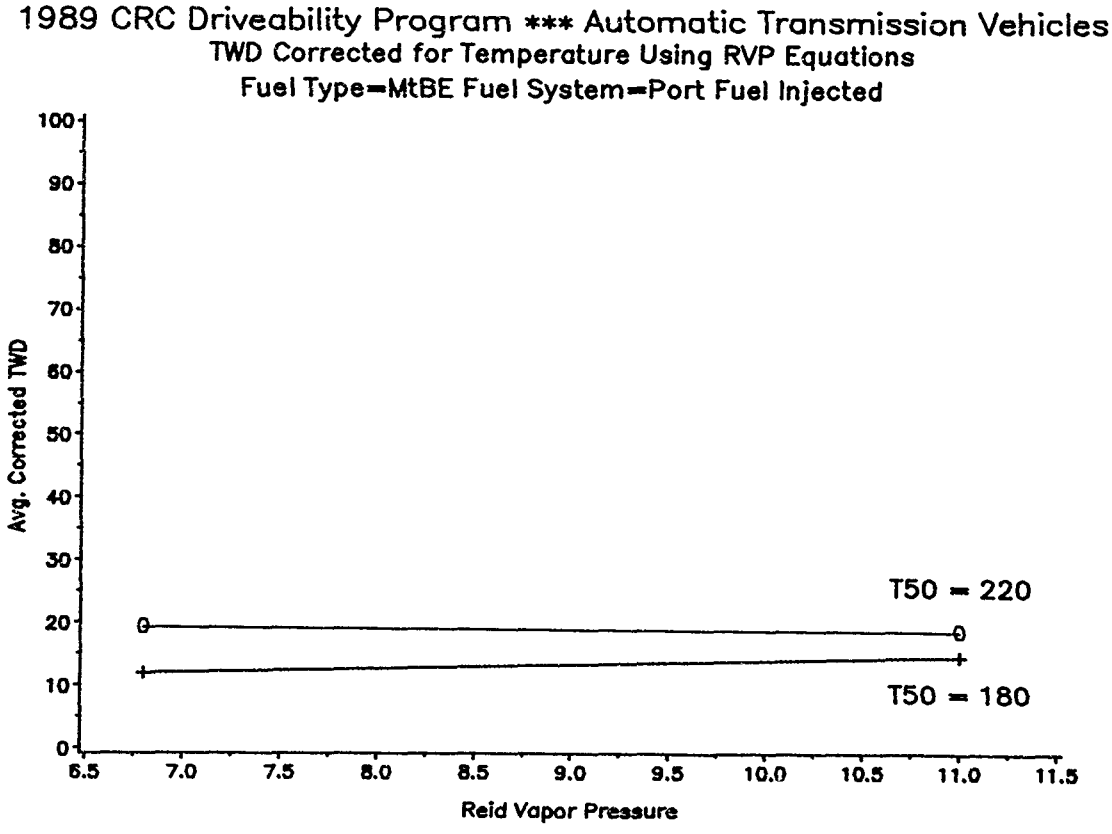

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MtBE Fuel System=Port Fuel Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 220
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-3

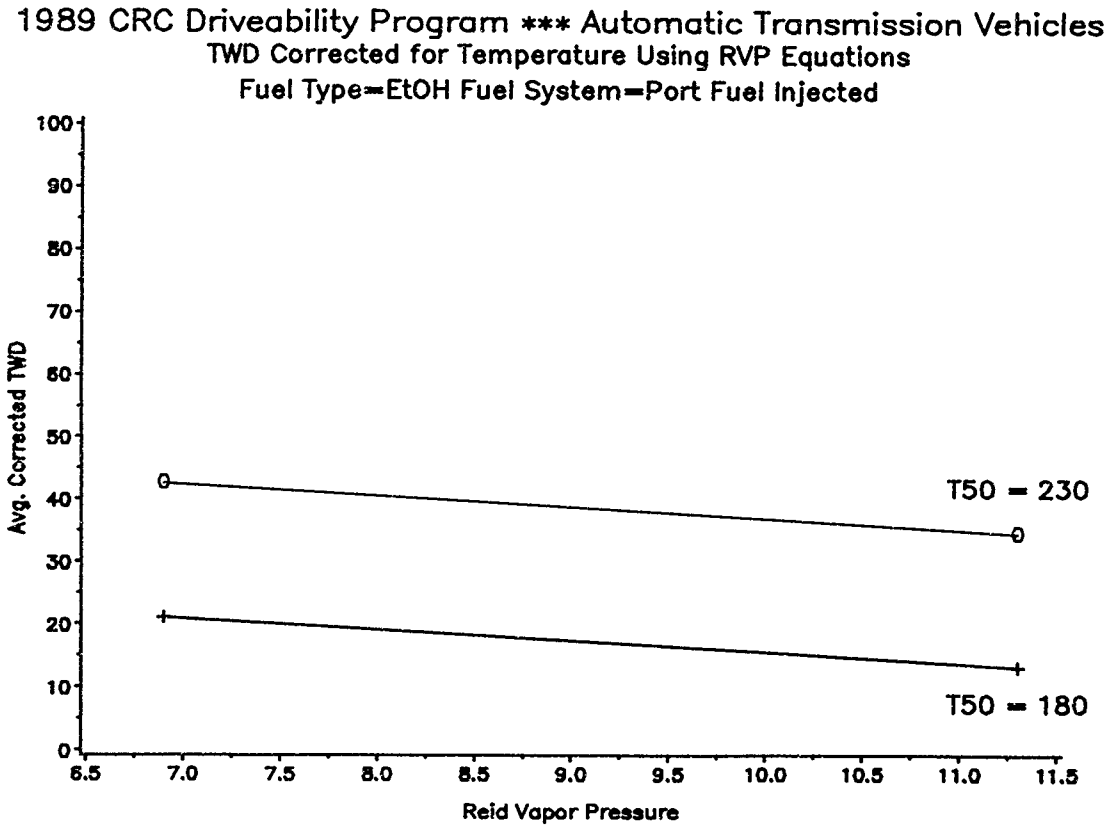

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Port Fuel Injected
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 230
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-4

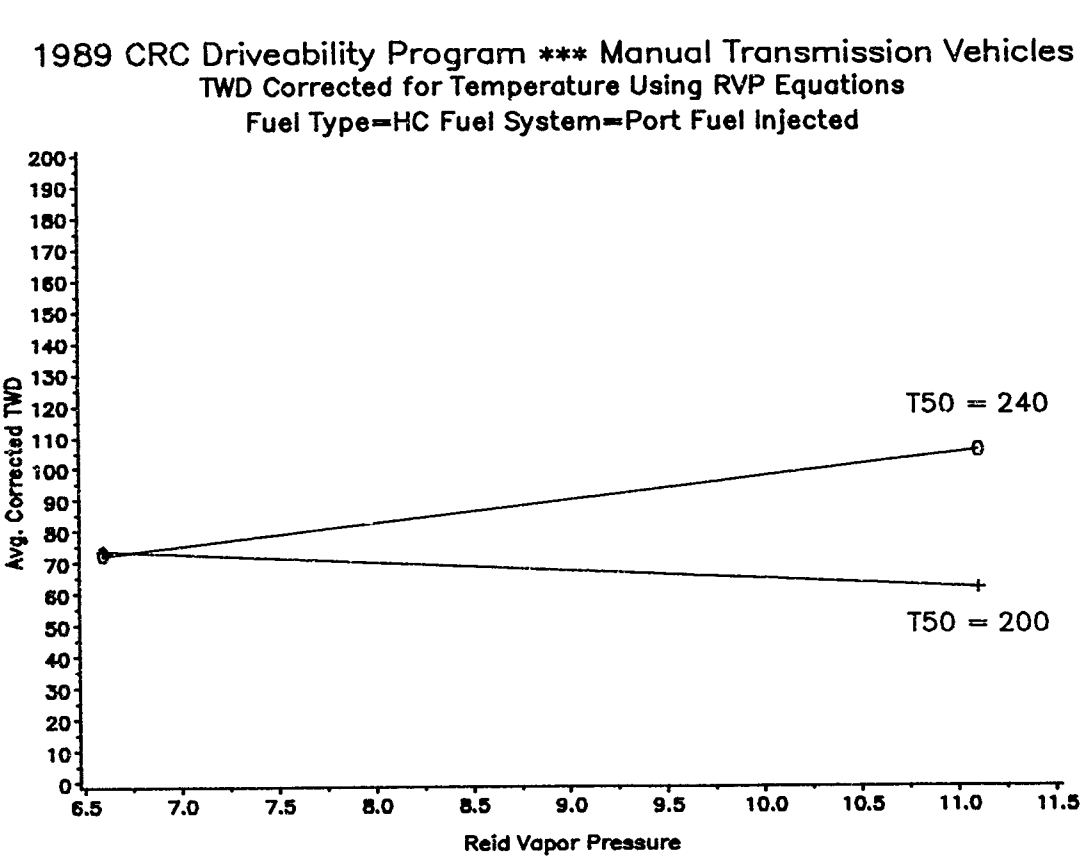

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Port Fuel Injected
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 240
T50 = 200

FIGURE H-5

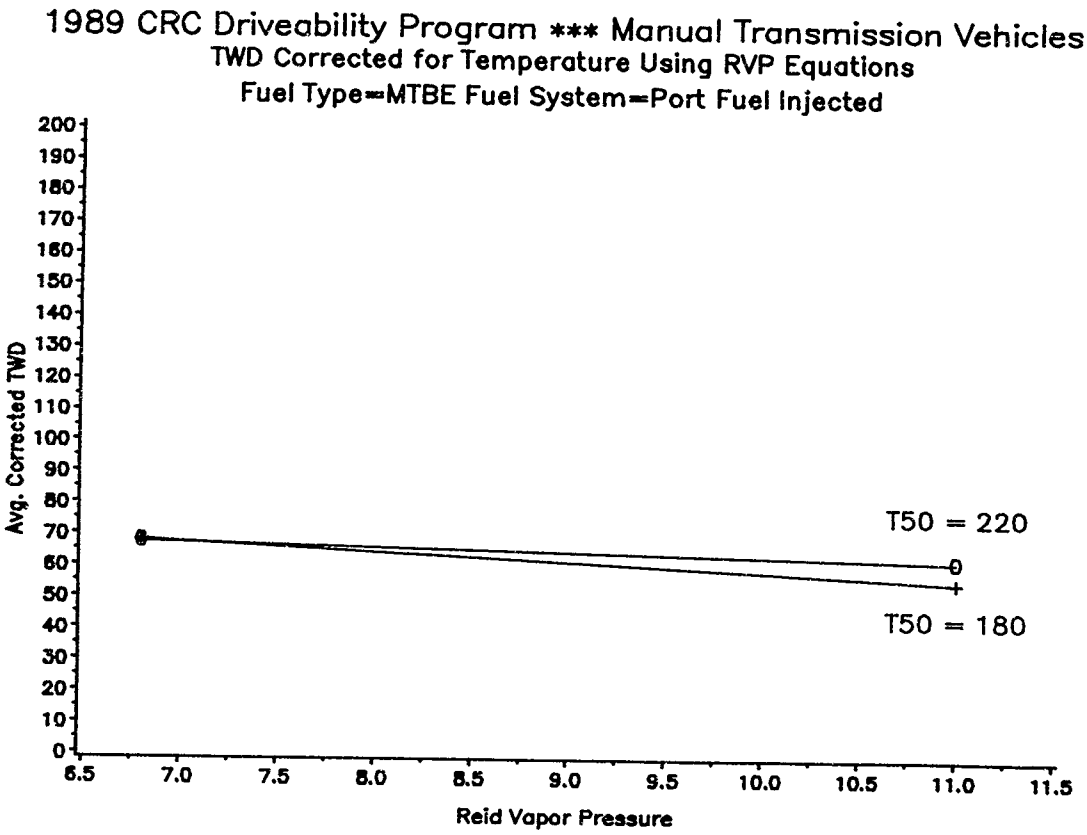

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE Fuel System=Port Fuel Injected
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-6

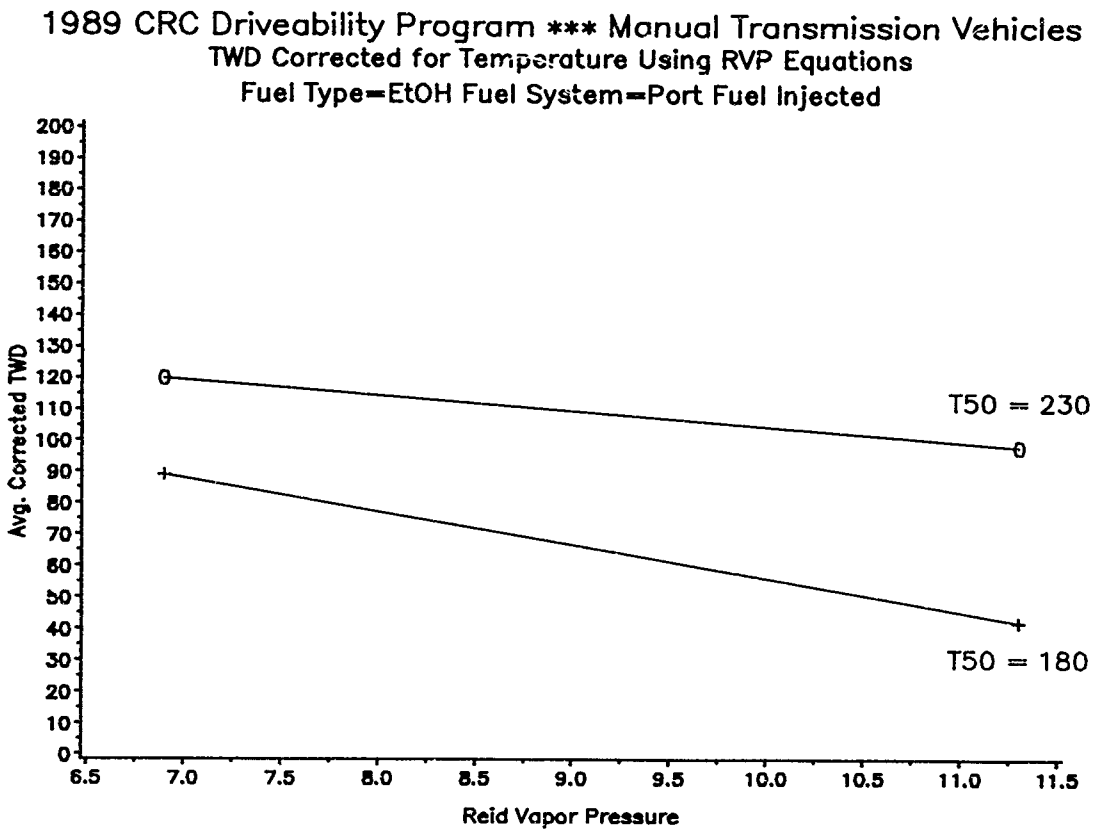

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Port Fuel Injected
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 230
T50 = 180

FIGURE H-7

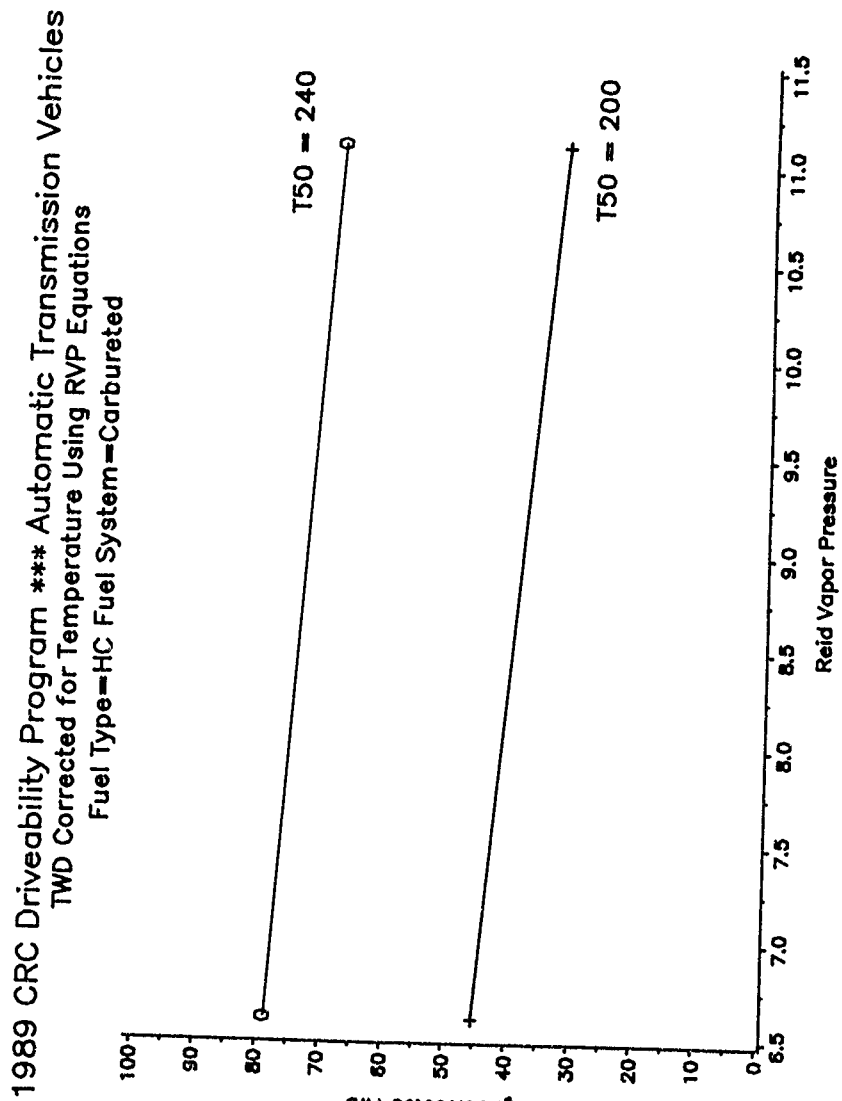

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Carbureted
T50 = 240
T50 = 200
Avg. Corrected TWD
Reid Vapor Pressure
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

FIGURE H-8

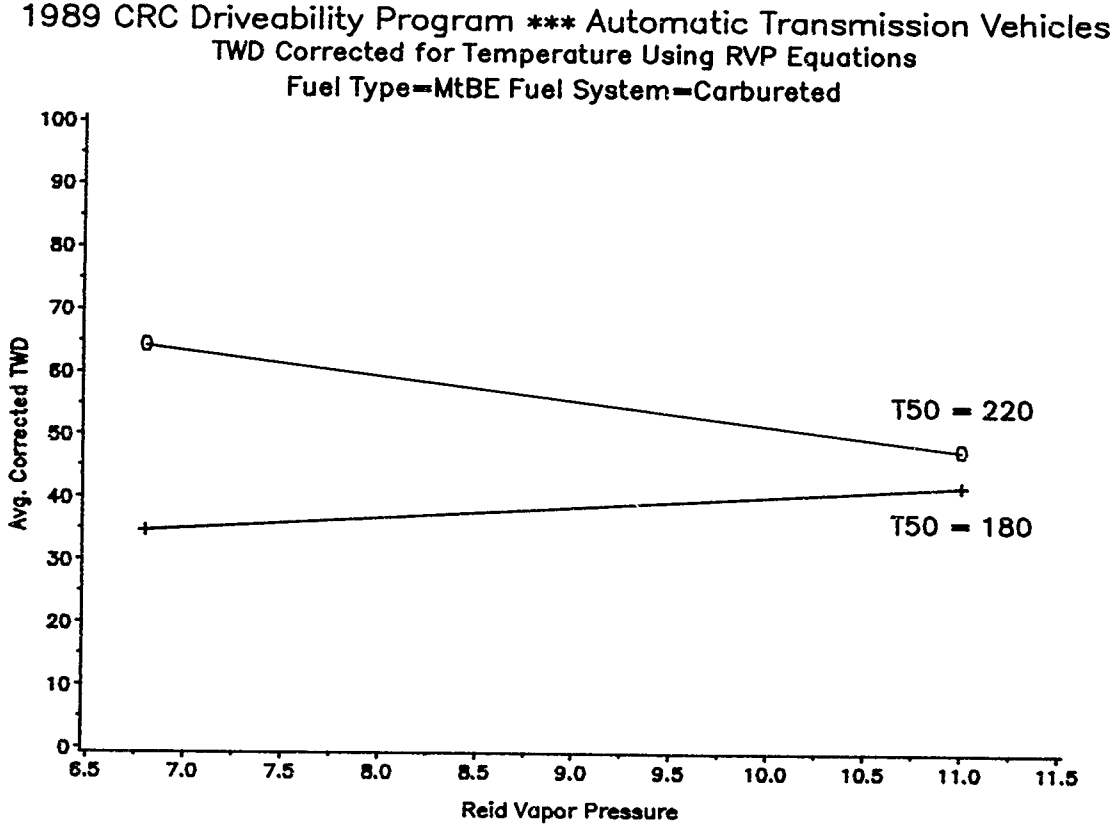

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MtBE Fuel System=Carbureted
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-9

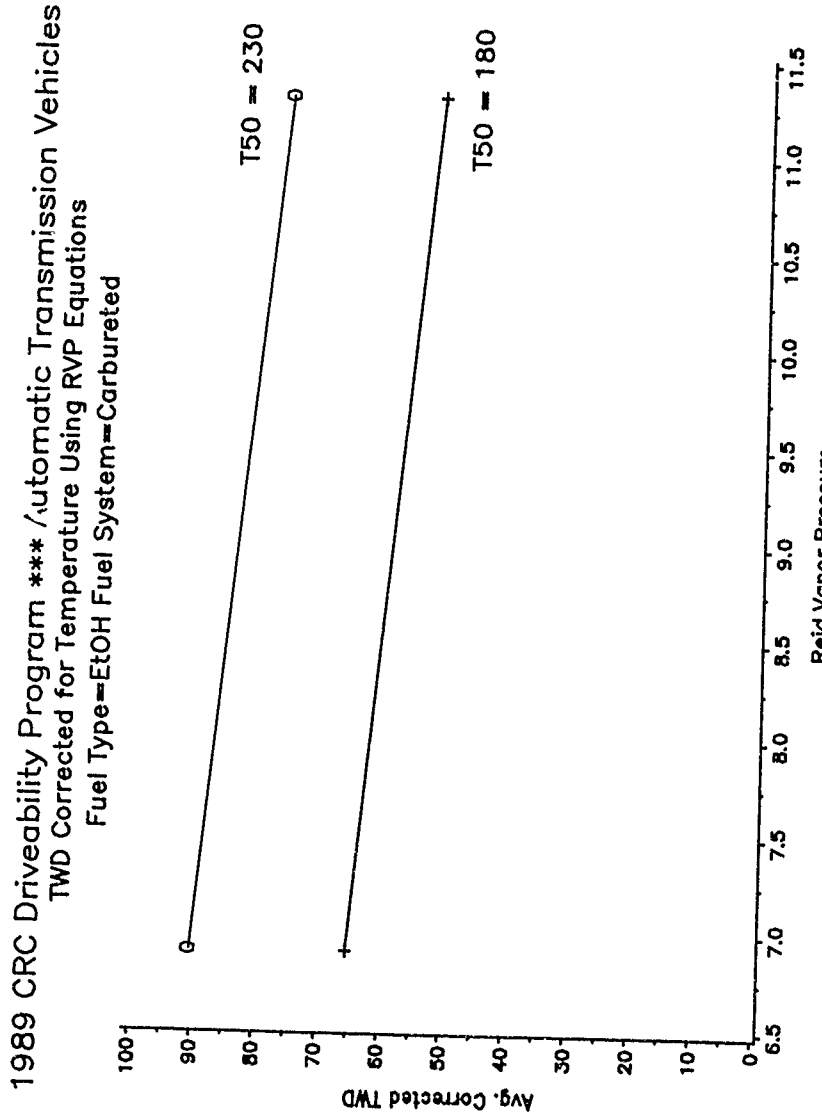

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Carbureted
T50 = 230
T50 = 180
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-10

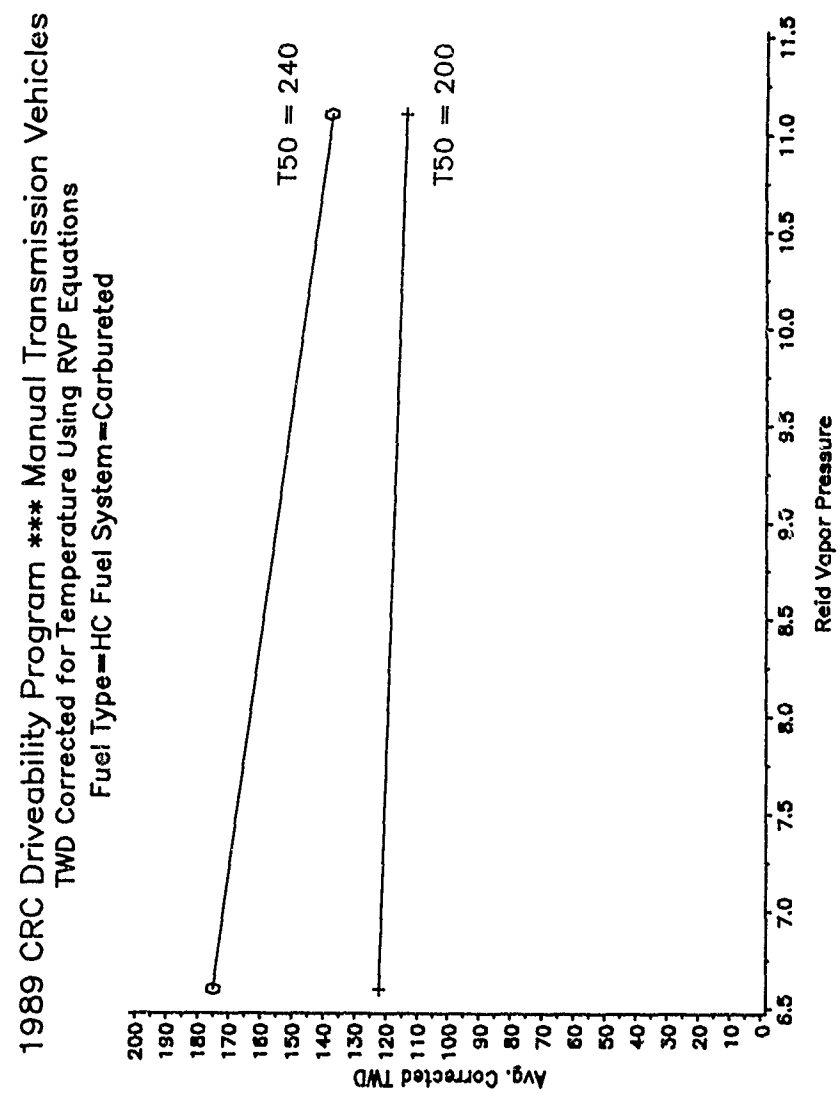

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Carbureted
T50 = 240
T50 = 200
Avg. Corrected TWD
Reid Vapor Pressure
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

FIGURE H-11

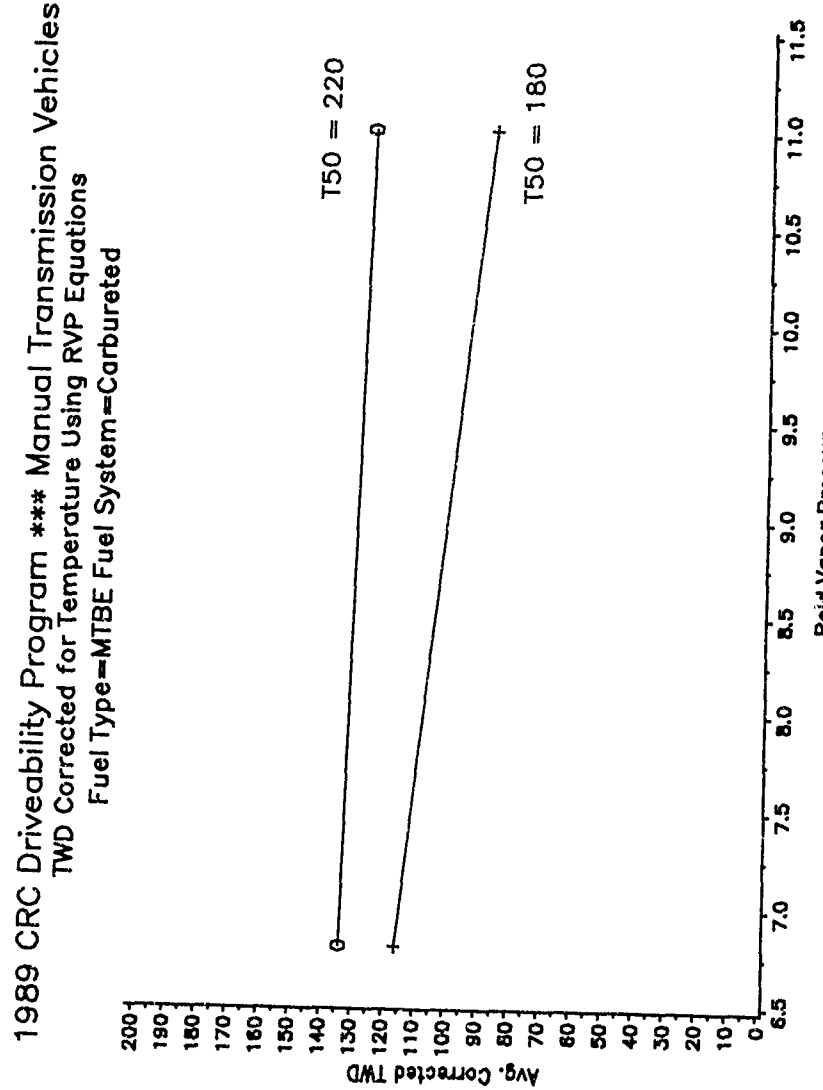

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE Fuel System=Carbureted
T50 = 220
T50 = 180
Avg. Corrected TWD
Reid Vapor Pressure
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

FIGURE H-12

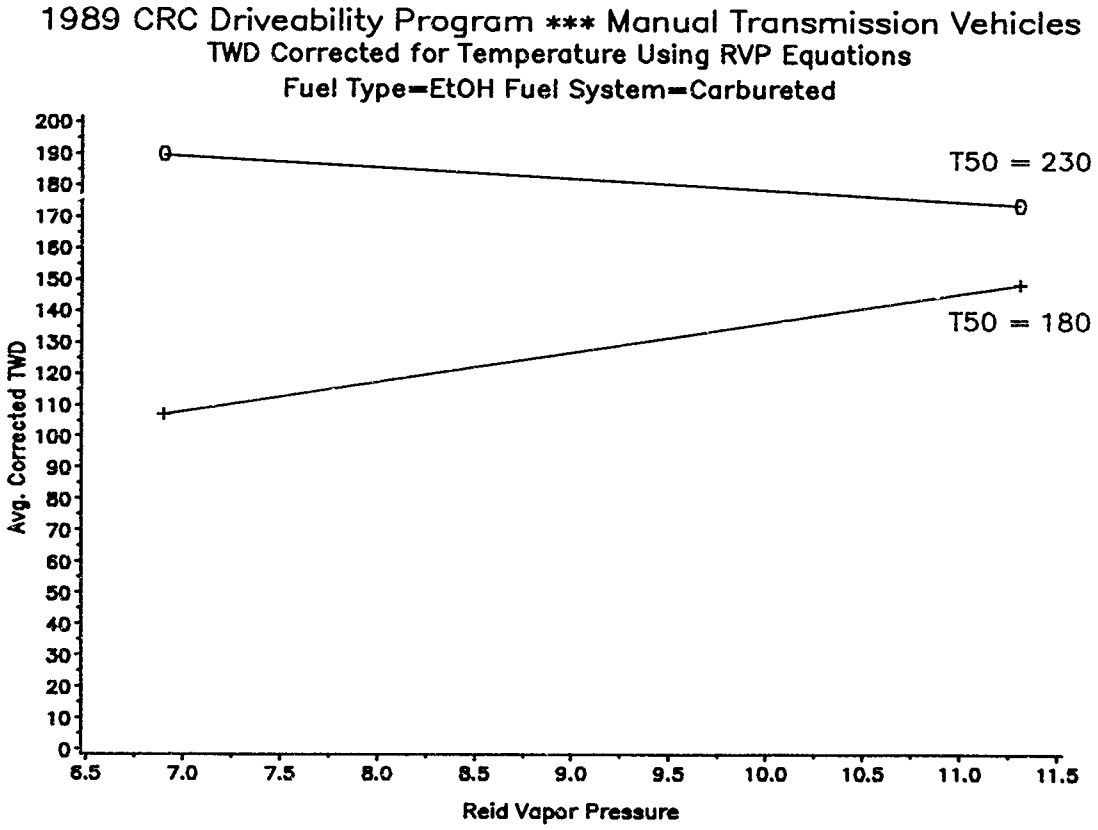

1989 CRC Driveability Program *** Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Carbureted
T50 = 230
T50 = 180
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-13

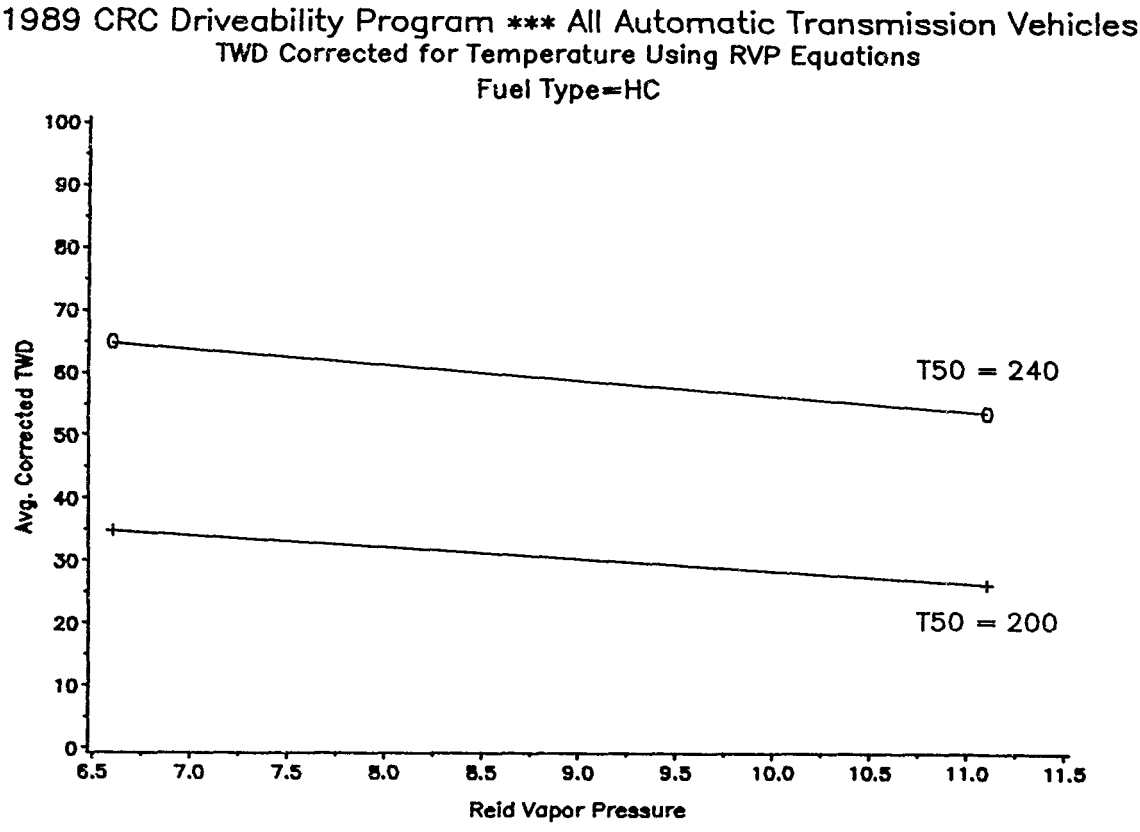

1989 CRC Driveability Program *** All Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 240
T50 = 200
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-14

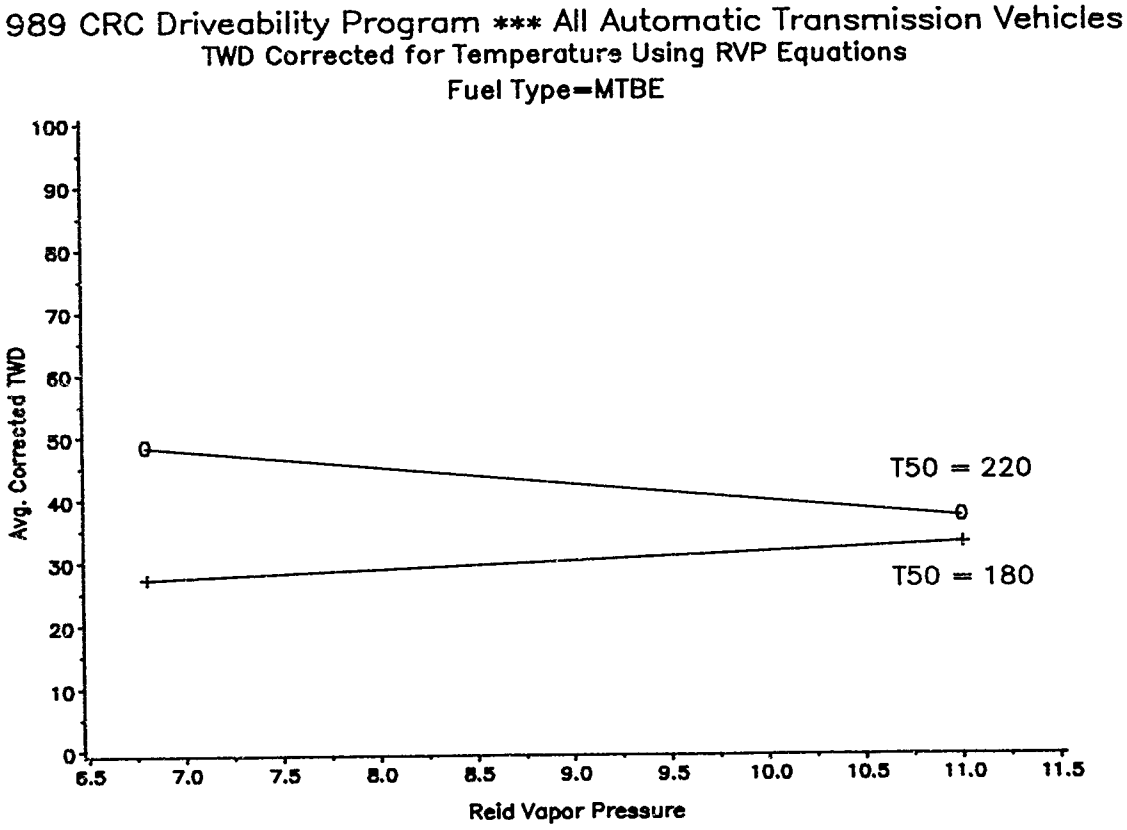

1989 CRC Driveability Program *** All Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-15

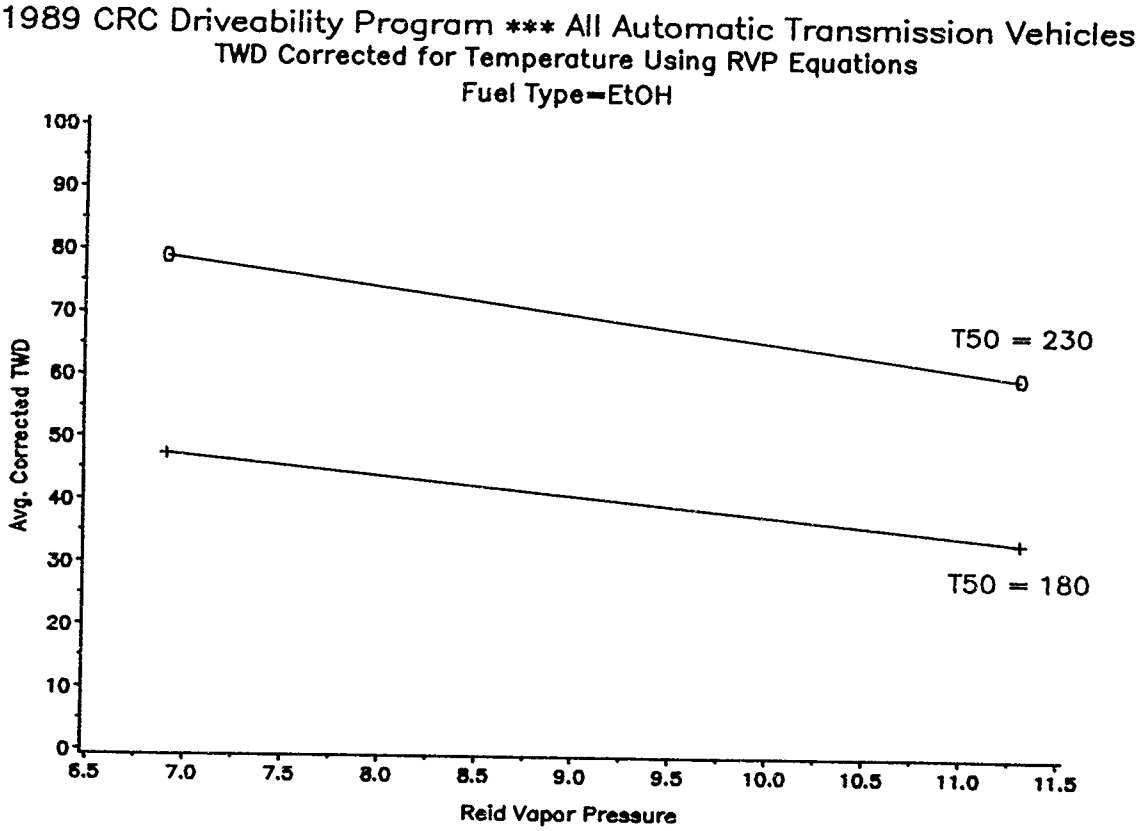

1989 CRC Driveability Program *** All Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 230
T50 = 180

FIGURE H-16

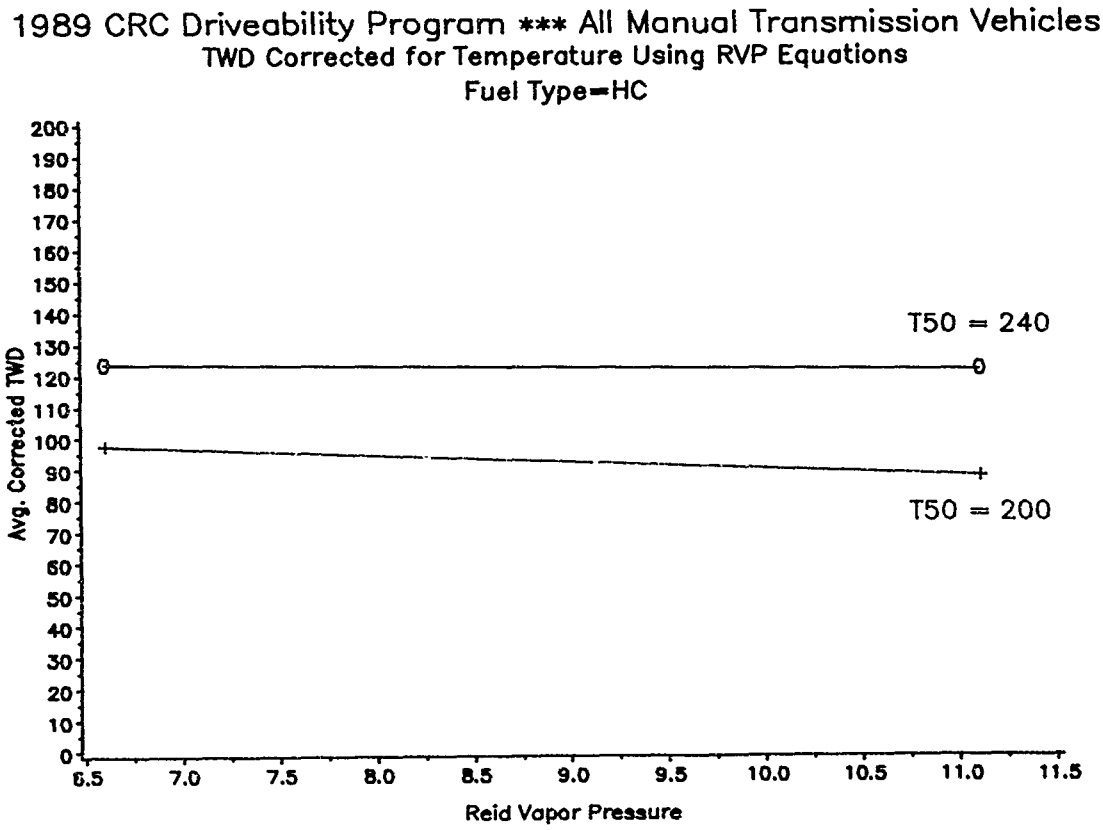

1989 CRC Driveability Program *** All Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
T50 = 240
T50 = 200
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-17

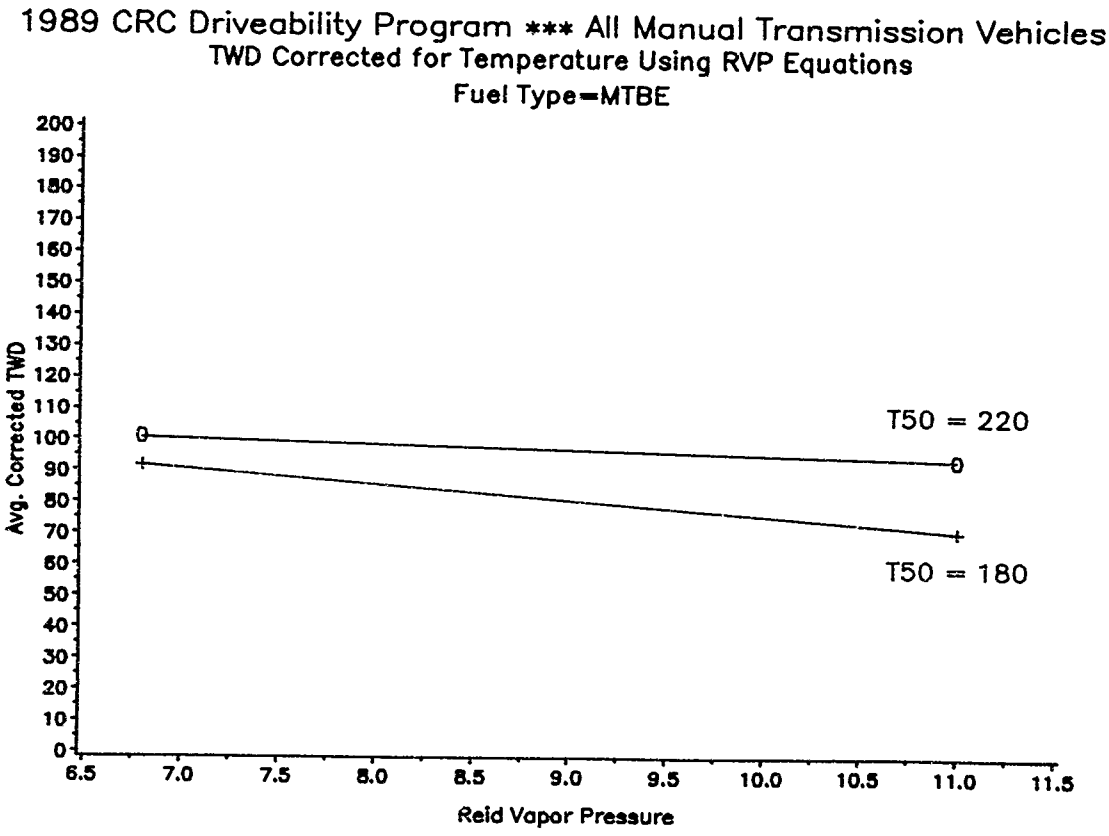

1989 CRC Driveability Program *** All Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-18

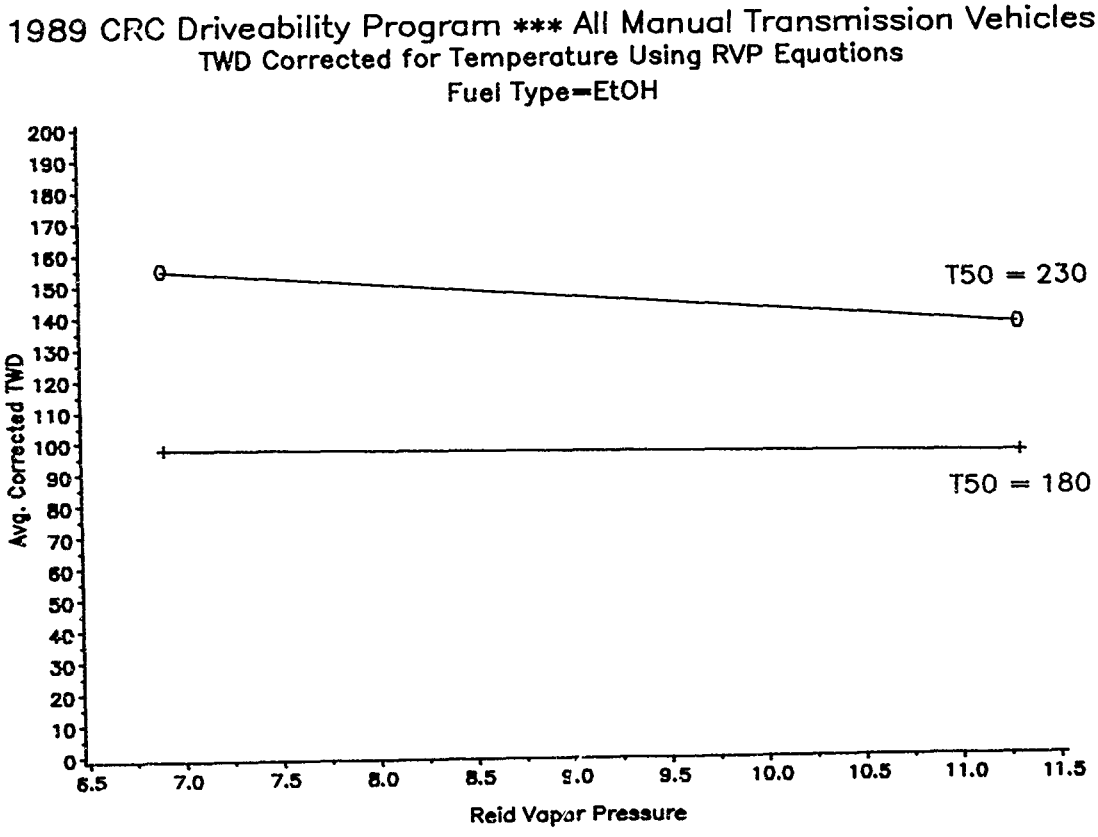

1989 CRC Driveability Program *** All Manual Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH
Avg. Corrected TWD
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
T50 = 230
T50 = 180
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-19

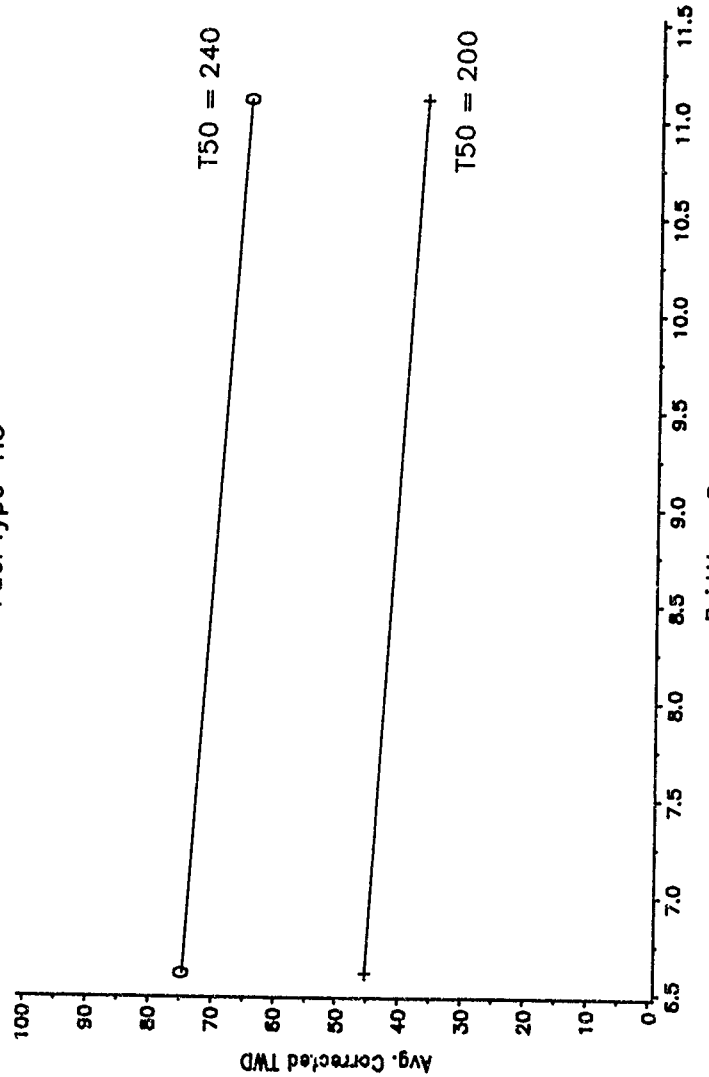

1989 CRC Driveability Program *** All Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC
T50 = 240
T50 = 200
Avg. Corrected TWD
Reid Vapor Pressure
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

FIGURE H-20

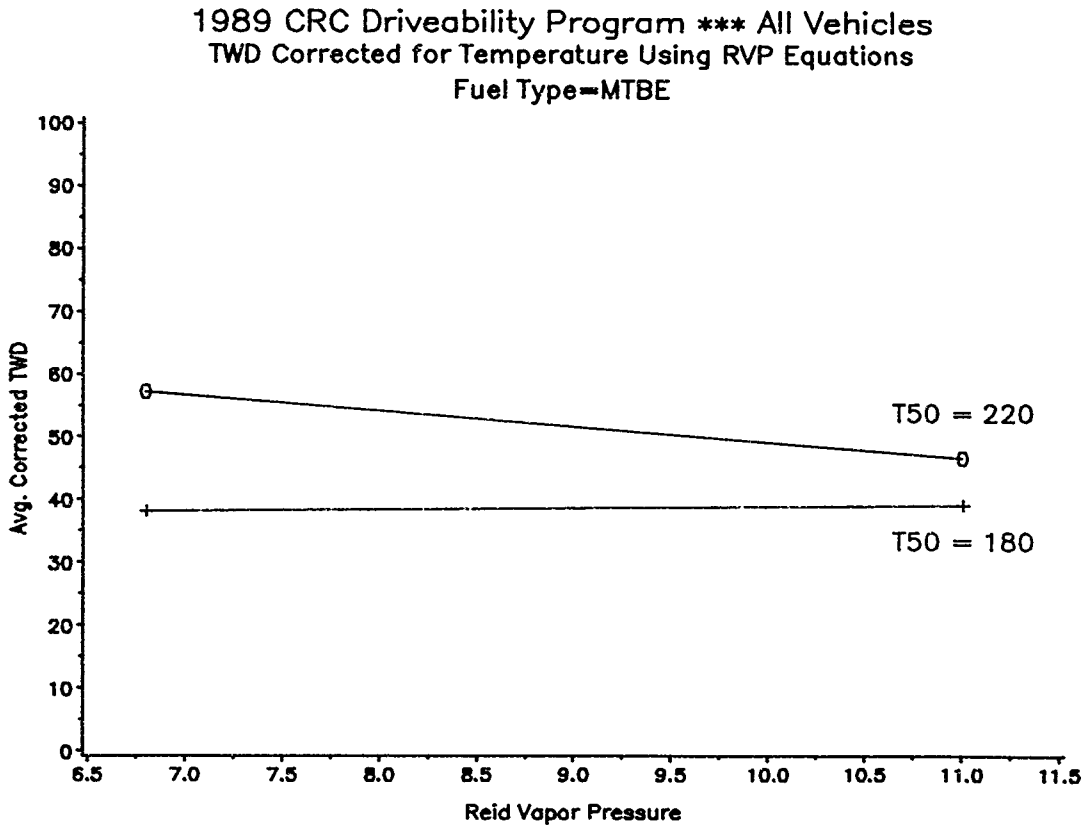

1989 CRC Driveability Program *** All Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MTBE
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-21

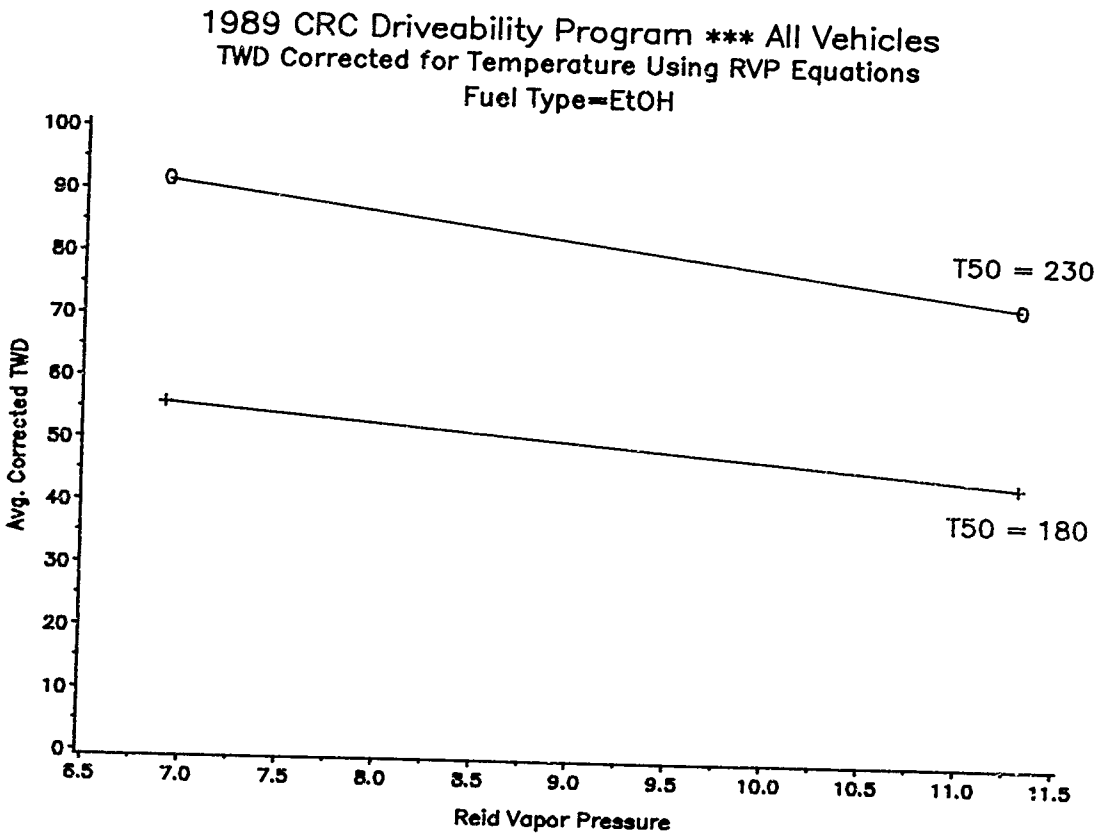

1989 CRC Driveability Program *** All Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 230
T50 = 180

FIGURE H-22

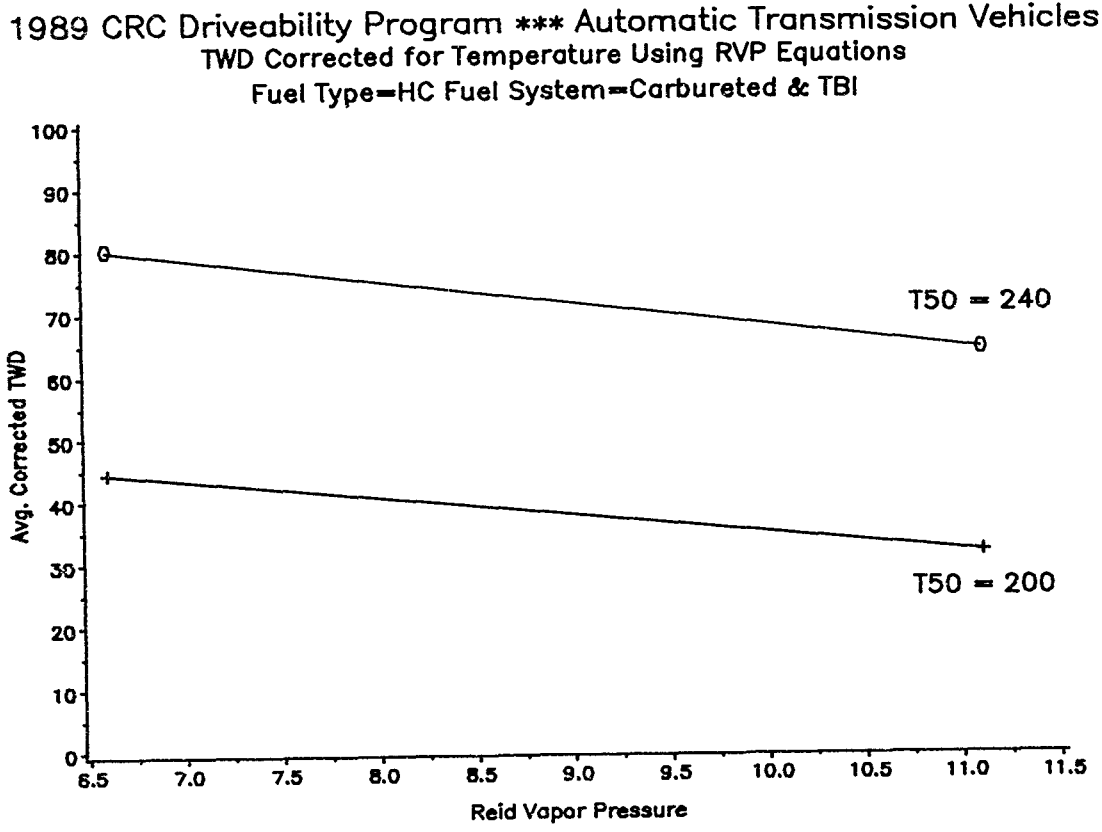

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=HC Fuel System=Carbureted & TBI
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
T50 = 240
T50 = 200
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure

FIGURE H-23

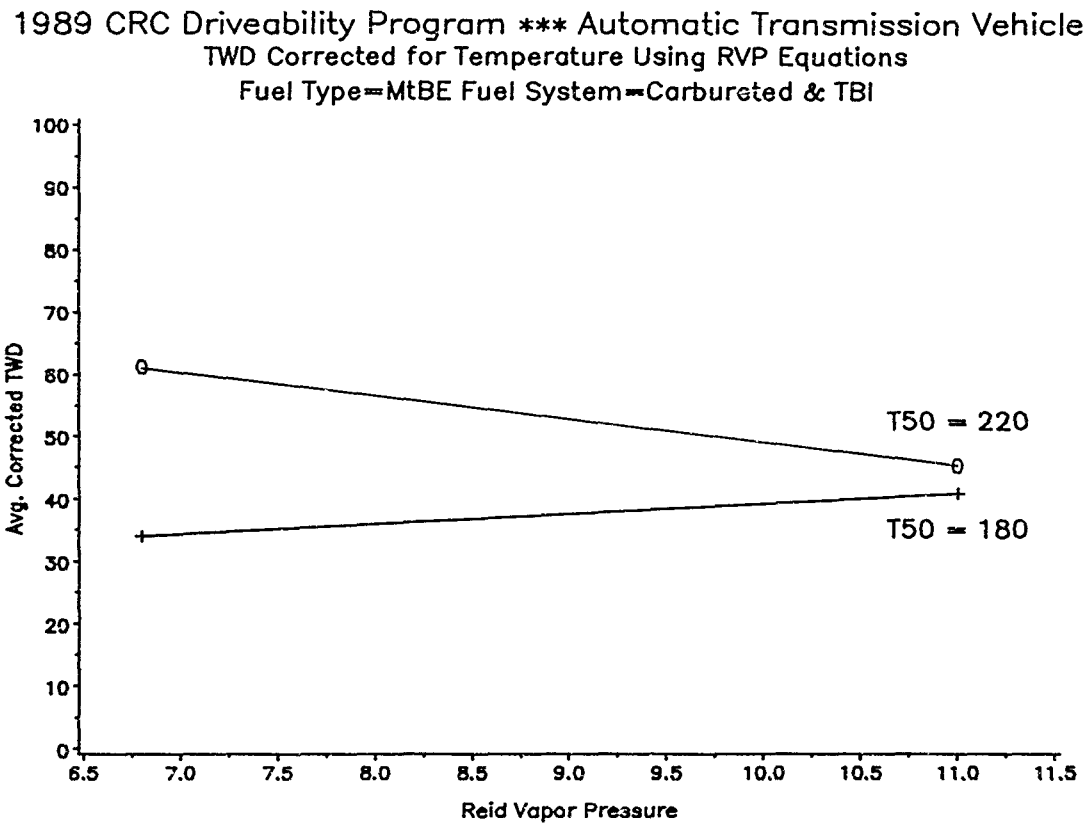
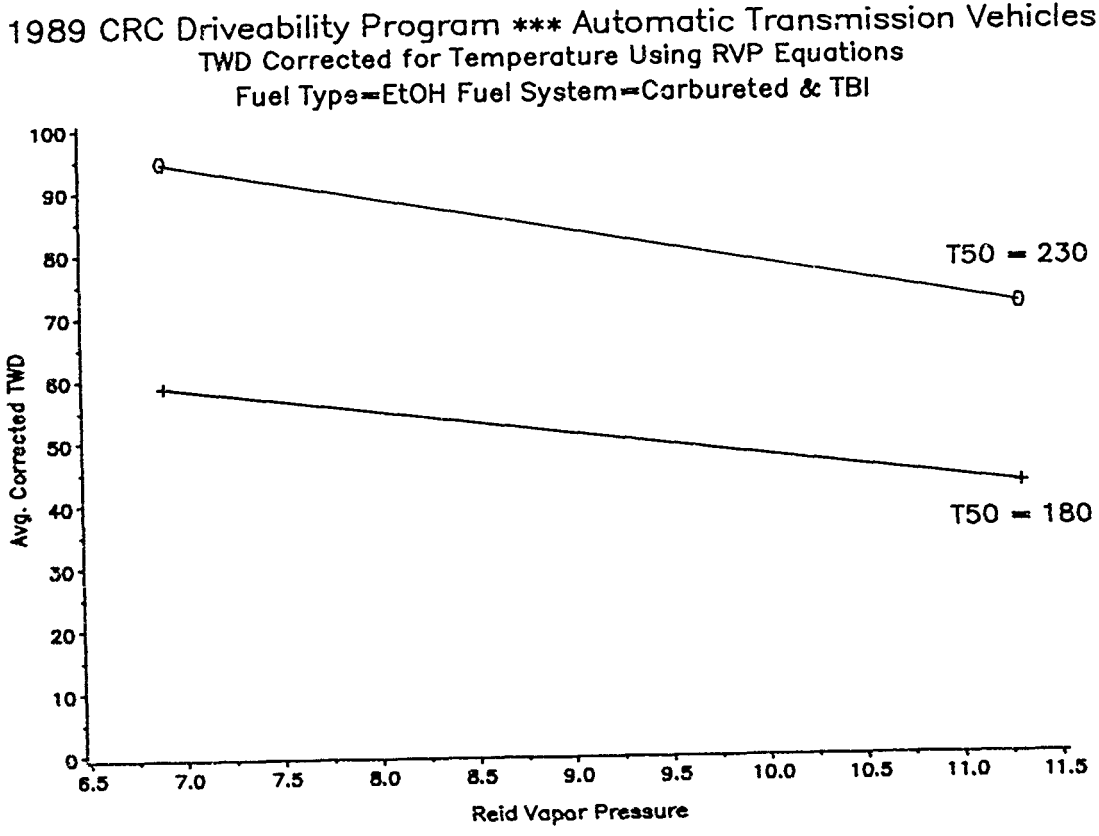

1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=MtBE Fuel System=Carbureted & TBI
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 220
T50 = 180

FIGURE H-24


1989 CRC Driveability Program *** Automatic Transmission Vehicles
TWD Corrected for Temperature Using RVP Equations
Fuel Type=EtOH Fuel System=Carbureted & TBI
Avg. Corrected TWD
100
90
80
70
60
50
40
30
20
10
0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Reid Vapor Pressure
T50 = 230
T50 = 180